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LX50

Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

MEADE
MAGELLAN II
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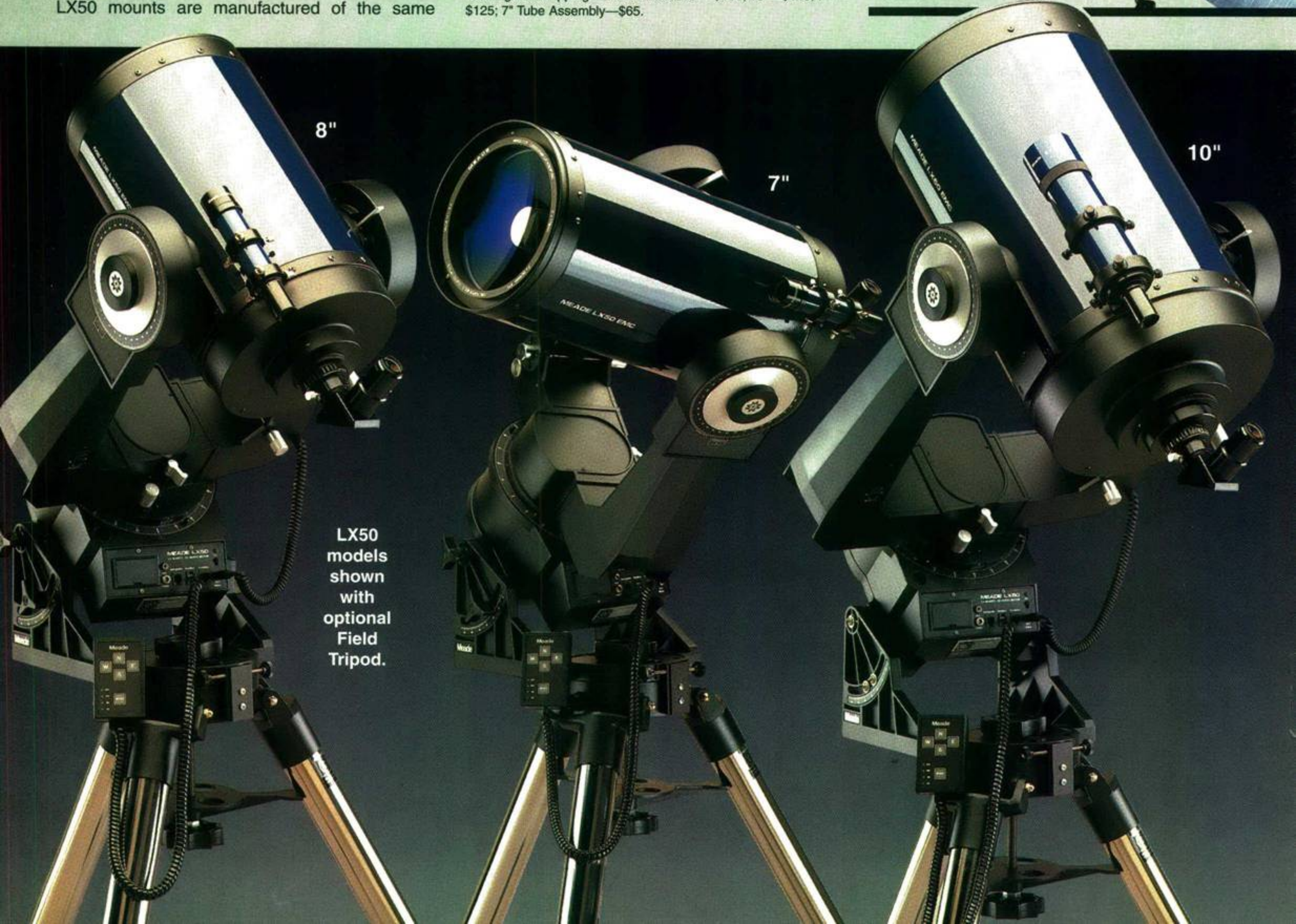
only $495!

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



LX50 models shown with optional Field Tripod.

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

MEADE LX200 EMC
8"
7"
10"
12"
Meade

Write, call, or fax Meade Instruments for your free copy of the 100-page Meade General Catalog.

Prices shown are suggested U.S. mail-order retail prices.

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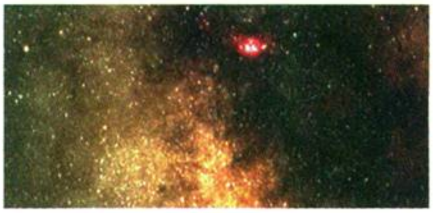

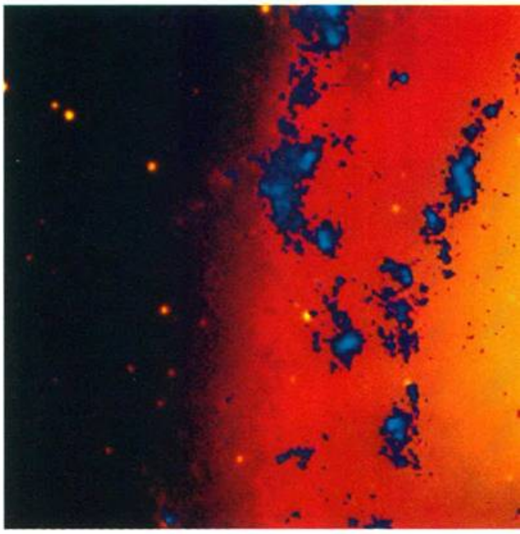

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Originally published in *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

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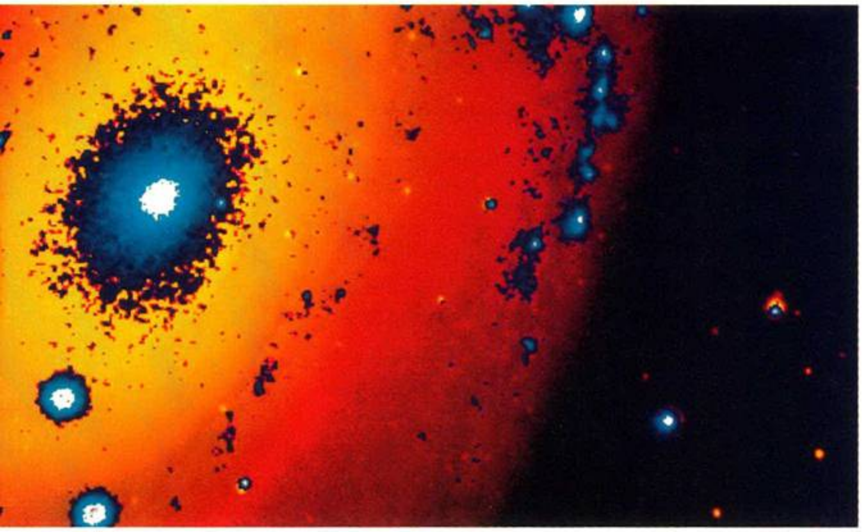

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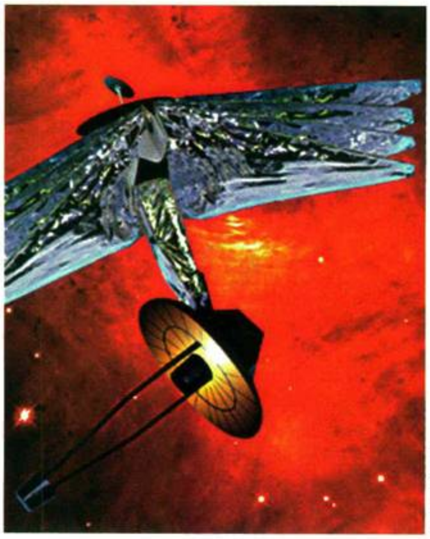
BEHIND THE SCENES

BY BONNIE BILYEU GORDON

When Telescopes Fly

At the American Astronomical Society's annual meeting in January 1998, a great deal of discussion went toward naming the replacement for the Hubble Space Telescope. This may come as a surprise to those of you who thought that the Hubble might be with us forever. It is, in fact, scheduled for retirement in seven years. The Hubble has opened a much wider universe than the one we knew, proving good theories, squashing others, and pushing scientists to come up with new ones. Eight years into orbit, the Hubble has outlived the flak it drew initially because of a poorly configured mirror.


Ball Aerospace

One of four designs for the Next Generation Space Telescope.

We are led to believe the Hubble will be followed by a telescope that will expand even further — our view to just about the beginning of time. If that seems astonishing, look for much more in Anne Kinney's story, "When Galaxies Were Young," on page 44. She is one of the astronomers hard at work planning the Next Generation Space Telescope. She was kind enough to give us a glimpse behind the scenes and an indication of the far-reaching hopes for it held by many researchers.

Jon Goel

Anne Kinney is an astronomer at the Space Telescope Science Institute in Baltimore, Maryland, and a member of *Astronomy*'s editorial advisory board.

She also took some time in Washington to sit down with the editors of *Astronomy* (and some other remarkable researchers) and explain a good deal more about the future she envisions. But we're saving that for another issue.

In the meantime, we invite you to have a little fun with the story "Close-up of a Comet Crash" on page 42, which tells how scientists gave guidance to Hollywood movie makers when they filmed *Deep Impact.*

Crater expert Eugene Shoemaker was a consultant for *Deep Impact* before his life came to a tragic end. He died in an accident in Australia in July 1997. Shoemaker is the subject of a profile by senior editor Rex Graham called "Making an Exceptional Impact" on page 36.

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ASTRONOMY (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial phone: (414) 796-8776; advertising: (800) 558-1544; customer service: (800) 446-5489; subscriptions: (800) 533-6644, 7 days a week, 24 hours a day; fax (414) 796-0126.
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Periodicals postage paid at Waukesha, WI, and additional offices. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription price: 1 year $34.95, Canadian and foreign: 1 year $45, payable in U.S. funds (*Canadian price includes GST*). *BN* 12271 3209 RT. Canadian International Publications Mail Products Agreement 545-775. Not responsible for unsolicited materials. POSTMASTER: Send address changes to *ASTRONOMY*, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612.

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Model 127NT/500:
5" f/8 Newtonian
Reflector — **$695.**

Model 203SC/500:
8" f/10 Schmidt-Cassegrain
— **$1295.**

Shown with optional #1702 Dual-Axis Drive System

MEADE 500-Series

Experience all of the high-resolution optical performance and mechanical precision of a MEADE reflector, refractor, or Schmidt-Cassegrain, at a moderate pricing level. Each complete 500-Series model includes the all-new MEADE LXD 500 equatorial mount with dual-axis worm gears, engraved setting circles, micrometric slow-motion controls in RA and Dec, rigid aluminum tripod, and a full complement of accessories. Choose from among five models the one that's right for your budget and observing requirements. *For complete details send for your free copy of Meade Bulletin 500.* Optional systems for Meade 500-Series telescopes include:

#1701 Single-Axis RA Drive System	**$145.**
#1702 Dual-Axis Drive System, with 4-speed hand controller	**195.**
#812 Polar Alignment Finder	**49.**

Prices shown are suggested U.S. national mail-order retail prices.
Packing and shipping: 4" models—$55; 4.5" and 5"—$45; 8"—$65.

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Meade Pictor 208XT
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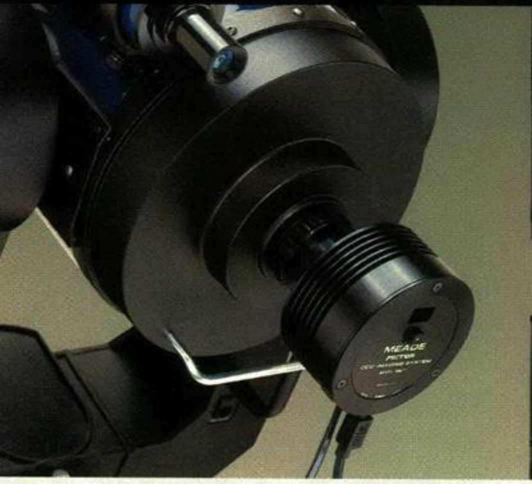
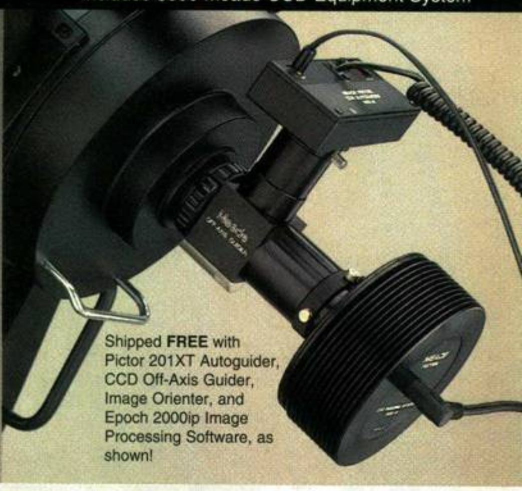


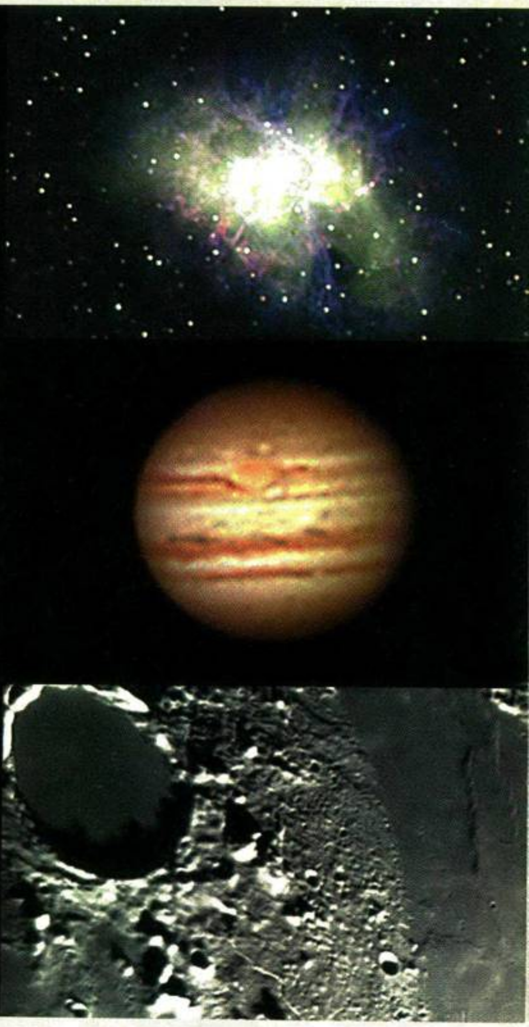


Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 94-page Meade 1997 General Catalog.***

Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.

Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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MEADE ETX

90mm Maksutov-Cassegrain

Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope— Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$595***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$595*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

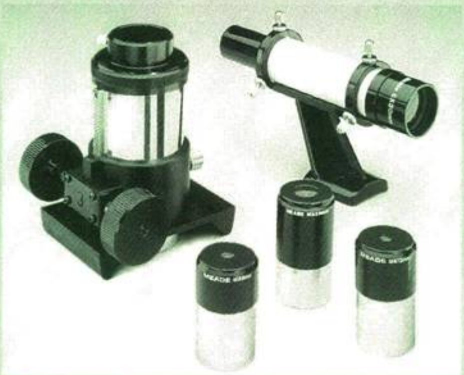
5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package
only $49.95!



Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- **1 - Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- **1 - Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- **3 - Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I
Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

MEADE
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MODE
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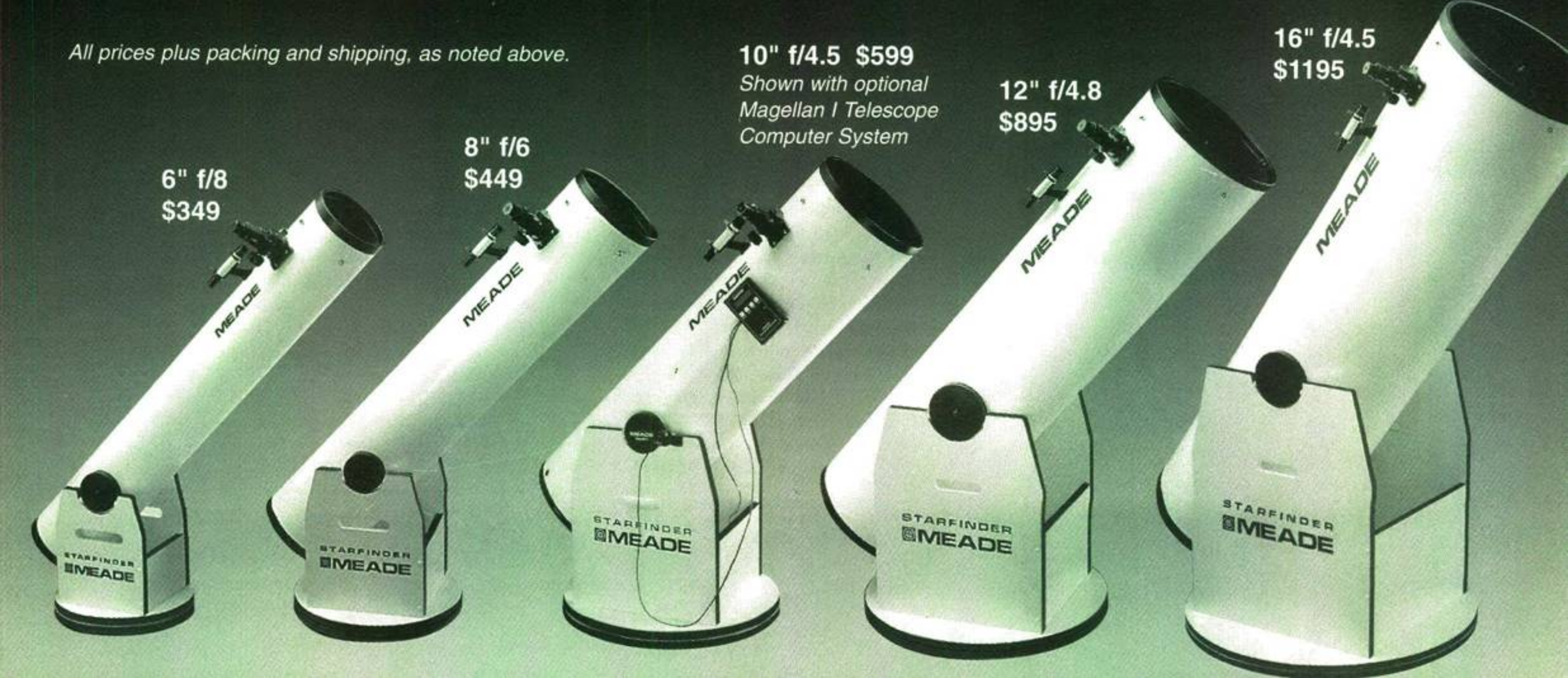
NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



All prices plus packing and shipping, as noted above.

6" f/8
$349

8" f/6
$449

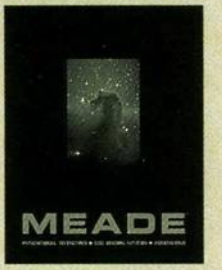
10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*



The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 100-page Meade General Catalog.

Write, call, or fax Meade Instruments for your free copy!

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.

#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.

#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

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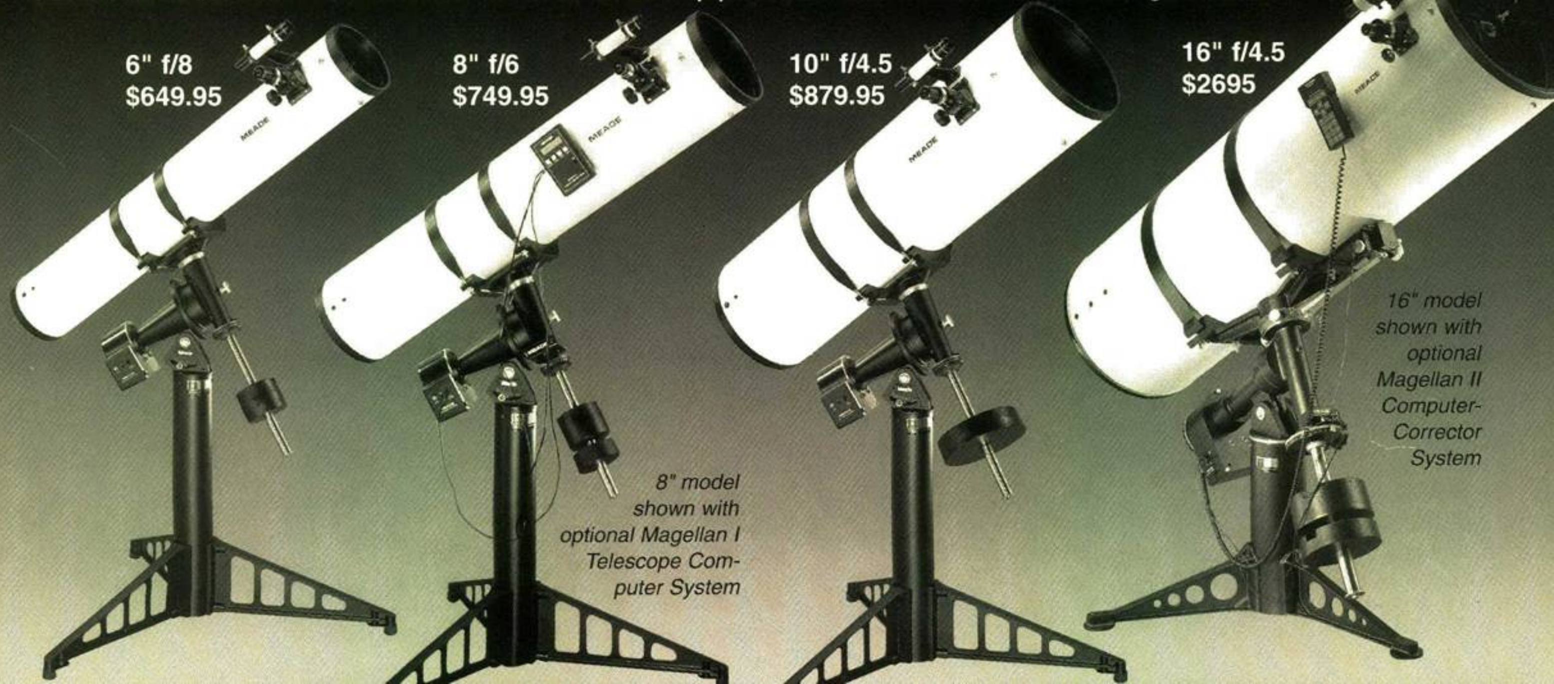
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



6" f/8
$649.95

8" f/6
$749.95

10" f/4.5
$879.95

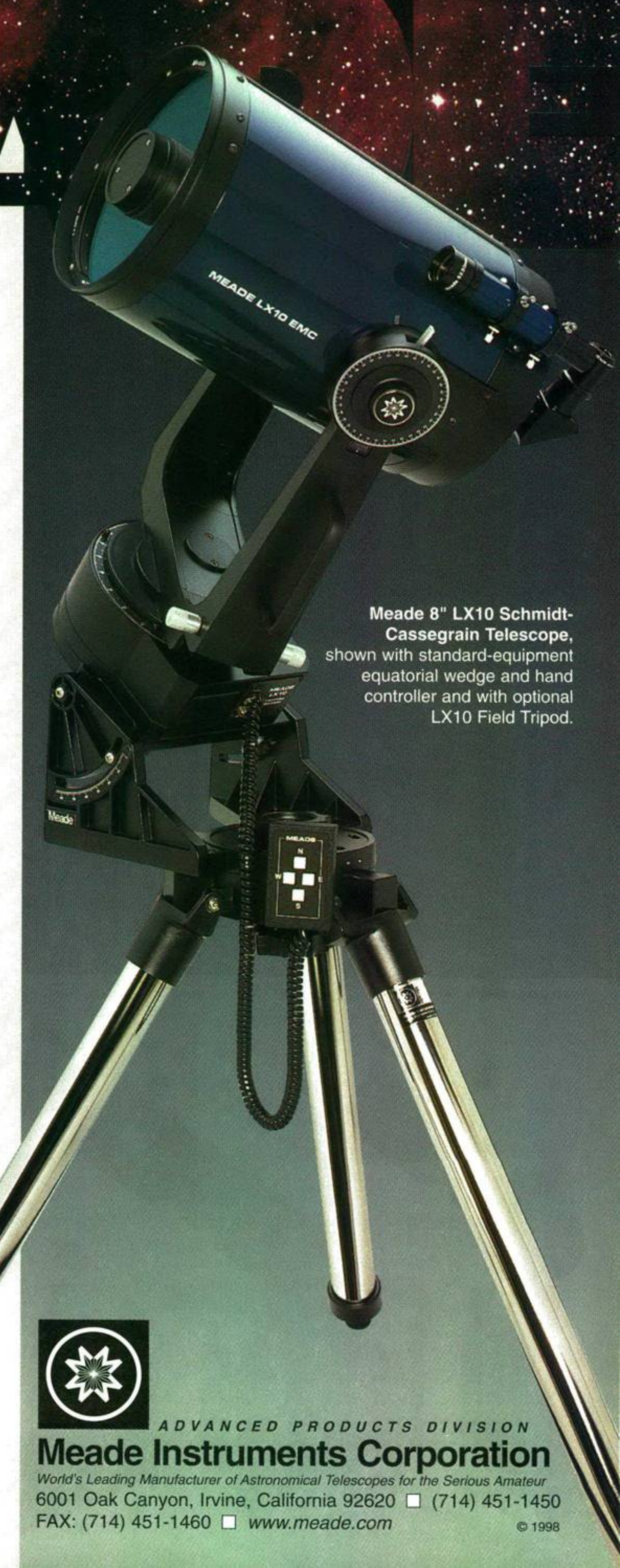
16" f/4.5
$2695

8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

8" LX10
8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*


Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) a premium-grade Meade Series 4000 Super Plössl 26mm eyepiece (in place of the standard MA25mm eyepiece); and (c) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed—all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; and with Meade #544 8 x 50mm achromatic viewfinder and Series 4000 Super Plössl 26mm multi-coated eyepiece included in place of the 6 x 30mm viewfinder and MA25mm eyepiece of the LX10. **$1149.** (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	195.
Electric Declination Motor System for LX10	95.
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	375.

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MEADE EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

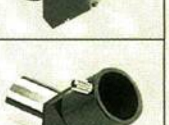
$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (5.87)

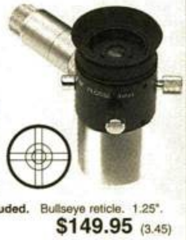
45° Erecting Prisms



Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#905 Variable Polarizer (1.25")

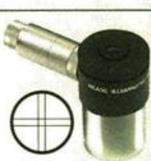
For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**, 1.25": **$29.95** (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

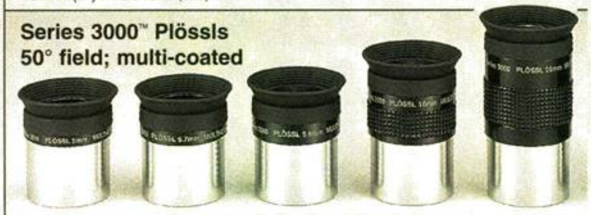
$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 3000™ Plössls 50° field; multi-coated



Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters; each eyepiece includes a fold-down rubber eyeguard for comfortable observing. Made exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

#911B
#910B
#908B
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#910N
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Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters; rubber eyeguard. Apparent field: 44°.

$79.95 (3.79)

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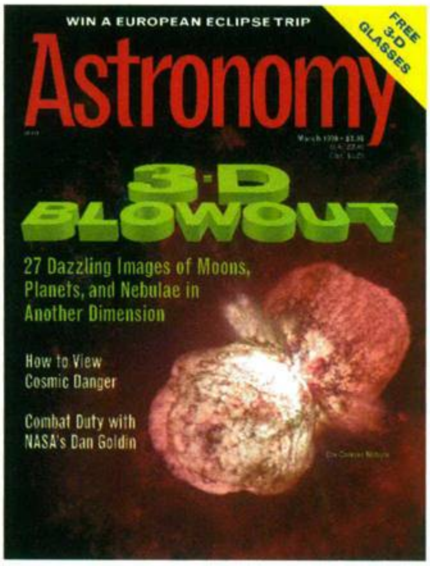
Three Cheers for 3-D

I have been a loyal and enthusiastic reader of *Astronomy* for about ten years. Today I witnessed a first. Despite my best efforts, I have never been able to get my children to even look at, let alone read, *Astronomy*. Today, my 16-year-old daughter saw the 3-D issue (March 1998) laying around. She not only picked it up and started looking at it, she even said, "Cool!" That's about as good as it gets with a teenager.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***Astronomy*'s March 1998 3-D cover**

I wish we all made a more concerted effort at making science fun. Having watched four children make it through school, I only wish that science was being taught with more fun in mind. We spend too much time, especially in the early years, trying to teach kids something, as opposed to piquing their interest. Thank you, *Astronomy*, for piquing my daughter's interest in science. — *Frank E. Hanou, Silver Spring, Maryland*

You really outdid yourselves this time on the two articles, "Red Planet Rendezvous" and "The Universe in 3-D" (March 1998). The 3-D pictures are fabulous. What a great idea to include the 3-D glasses and photographs to further bring the wonder and information home not only to your readers, but to school children and educators as well. — *Carole Pleskovic, Northfield, Ohio*

Problems with the Pentax Eyepiece Review

I noted with interest Steve Edberg's article in the January 1998 *Astronomy* on the fine new Pentax eyepiece line. While I can forgive him for mistakenly naming Tele Vue Wide Field eyepieces "Wide Angle" and incorrectly referring to the 28mm Panoptic (I presume he must mean our 27mm Panoptic), some other aspects of the review are more troubling. Our own tests do not show significant transmission differences that would enable users to see fainter stars with the Pentax models. Though there was no numerical evaluation, judgments were made based on comparisons with old eyepieces, including our long discontinued Wide Field models. If fair comparisons are to be made, "fresh" style models should be used.

Considering that Steve acknowledged that Tele Vue eyepieces are not only wider but sharper at the edge, whether at f/4 or f/10, I am surprised he didn't note that seeing sharper stars also means seeing fainter stars over the outer portions of the field. Indeed, a two-power improvement in edge image "spot size" gain results in a four-power gain in star intensity, which prevents faint stars from blurring into the background.

I also can't figure out how he could say our 32mm Wide Field had a larger true field than the 40mm Pentax. Why wouldn't he conclude that our current 35mm Panoptic would make a more appropriate comparison? It also has much better distortion correction than the 32mm Wide Field. Since distortion is often misread as an image degrading defect, it would also have helped if Steve made it clear that distortion (typically pincushion-shaped) does not reduce sharpness. The book *Telescope Making* by Rutten and Van Venrooij treats this subject in some detail.

Designers have lots of choices, and both Vixen and Pentax have made good use of our "Nagler" eyepiece concept, by trading off field versus eye relief. As I need glasses more often, I now have a reason to appreciate long eye relief, and future Tele Vue products will doubtlessly reflect this. It will not change my philosophy, however, that sharpness over the field is the first goal.

My congratulations to Pentax on a very fine product line. — *Al Nagler, President, Tele Vue Optics, Inc.*

In Defense of Spectacle Wearers

I watch developments in eyepiece design with great enthusiasm, which is only dampened by the apparent unwillingness of developers to take into account the basic requirements of eyepiece-to-eye optimization.

Aerospace data show that approximately 30 to 50 percent of the population between 20 and 45 years of age, and by age 50, 80 percent, either wear or would benefit from corrective eyewear (glasses or contact lenses).

In order to meet this need, eyepieces should be designed to allow a spectacle wearer to see all points in the field of view, including the field stop, while comfortably locating his or her eye relative to the eyepiece.

This imposes, at a minimum, two conditions on the optical design: first, that the nominal first order eye relief be 25mm to accommodate the 95th percentile of users and second, that the spherical aberration of the exit pupil be sensibly correct. Unfortunately, while some manufacturers are approaching these requirements, most are not. These requirements become even more important as we embark upon the quest for wider angle eyepieces. — *R. A. Buchroeder, Tucson, Arizona*

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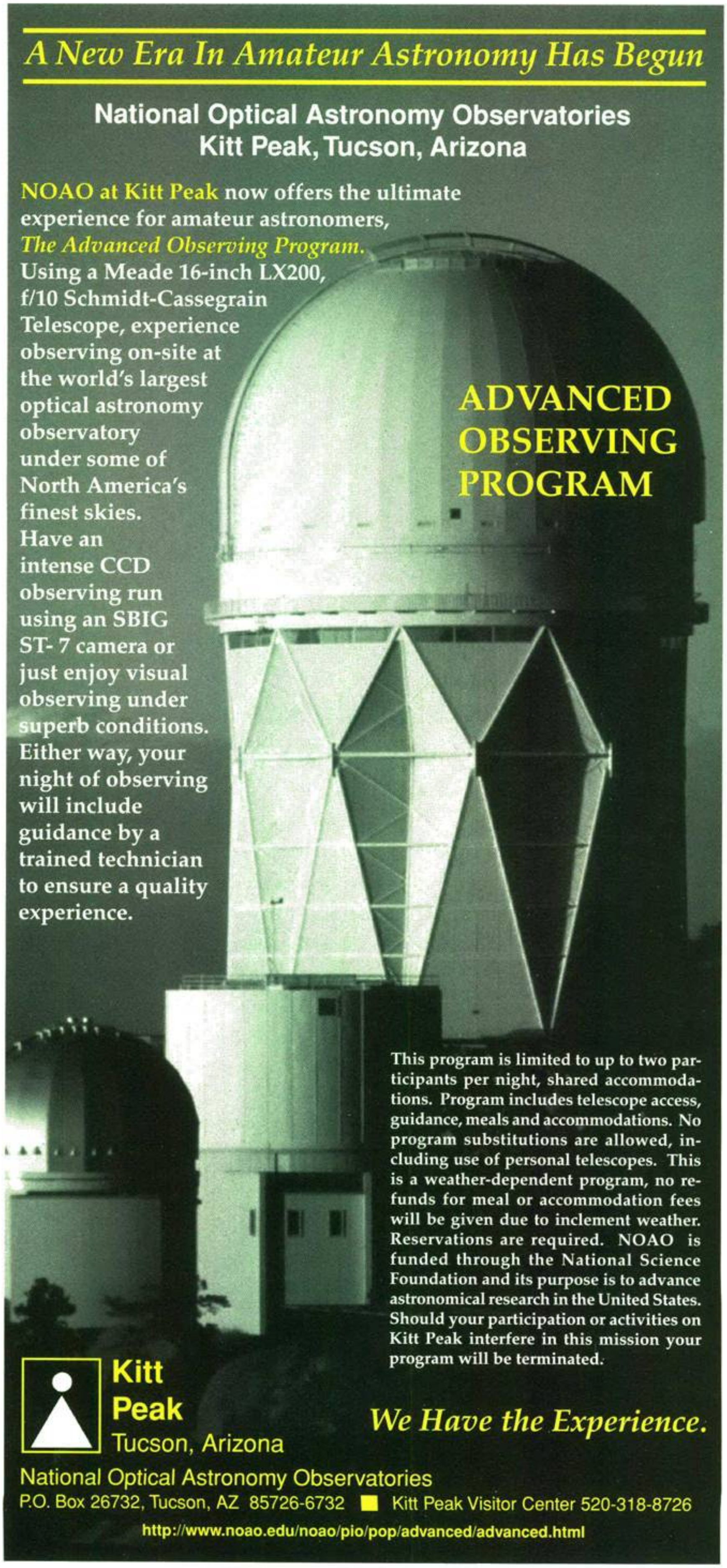

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Astronomy on the Go

To this weather-roiled easterner, Patricia Kurtz's story in the February 1998 issue ("Southwest Passage") was uplifting and informative. I'm very interested in learning of good astronomy locations in the West and thought her exploration of New Mexico's Sangre de Cristo Mountains was terrific.

Astronomy vacation destinations across the western United States would make fine subjects for occasional articles in *Astronomy*. The Star Hill Inn was unknown to me before the article. Let's hope that New Mexicans realize they harbor unique and valuable assets for all astronomers. — *Matt Ayers, Rochester, Massachusetts*

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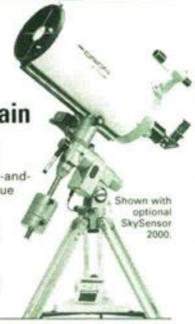

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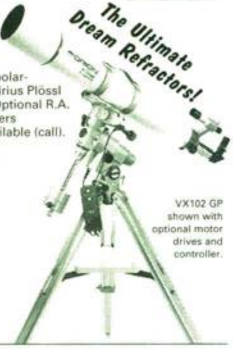

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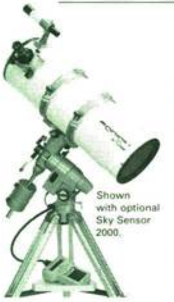

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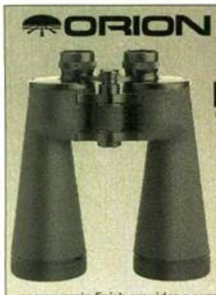

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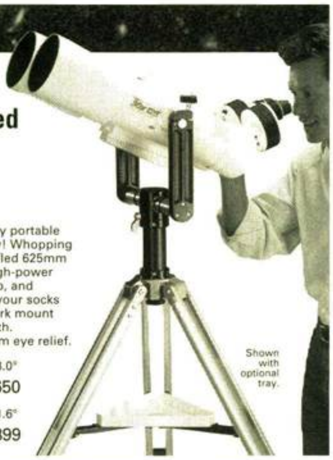

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SUPERNOVA 1987A

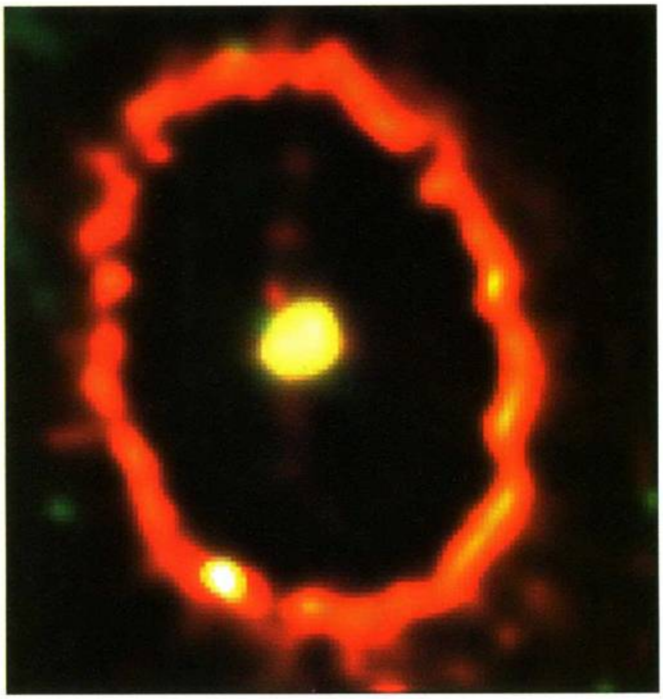
Let the Fireworks Begin

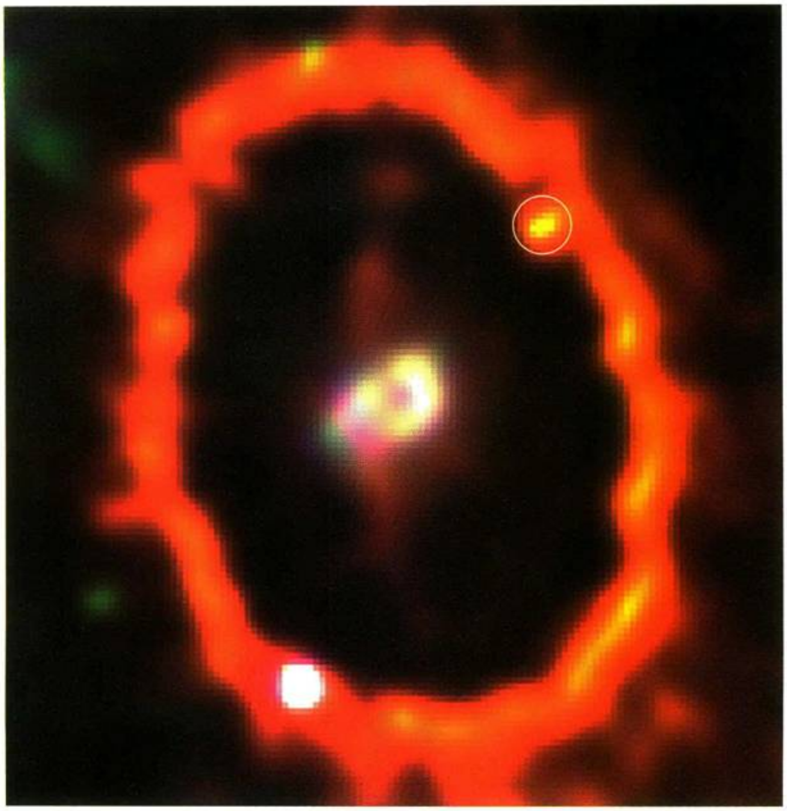
Blast Wave Runs into Inner Ring

▶ Like the next powerful California earthquake, astronomers knew it was going to happen, they just didn't know exactly when. But the waiting is finally over. A blast wave triggered by the star that exploded as Supernova 1987A has slammed into a ring of gas cast off by the progenitor star some 20,000 years before it exploded. A recently released Hubble Space Telescope image taken in July 1997 shows that the collision has lit up a 100-billion-mile-wide (160 billion km, or 1,100 astronomical units) knot in the inner edge of the ring, and this is only the beginning of an eagerly anticipated fireworks display.

Over the next few years, the 40-million-mile-per-hour (64-million-km-per-hour) blast wave will plow through the entire ring, compressing the gas and raising its temperature from a few thousand degrees F to a million degrees F. "In the next few years, we'll see more such spots light up until finally the whole ring is aglow. Ten years from now I expect the entire ring to be hundreds of times brighter than it is today," says Richard McCray of the University of Colorado.

Astronomers are hoping the collision will illuminate the surrounding space like a lantern in a cave, enabling them to see previously invisible clouds of gas. By seeing these clouds, astronomers will likely be able to reconstruct the formation of the ring, along with two fainter outer rings that were first imaged by Hubble in 1994. The event may confirm or reject an idea proposed by several astronomers: that the inner ring represents gas flung off into space when the progenitor star devoured a smaller binary companion. "By studying this collision with HST, we get to witness an event that promises to tell us a lot about the death throes of a massive star that's no longer there," says Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics.





TOP: In 1994, Hubble imaged the 1.4-light-year wide inner ring surrounding Supernova 1987A. BOTTOM: An image taken in July 1997 shows a new hot spot (circled) caused by a blast wave ramming into the inner edge of the ring. The supernova's expanding fireball lies in the center and a bright foreground star unrelated to the supernova is at the lower left.

Peter Garnavich (Harvard-Smithsonian Center for Astrophysics) and NASA

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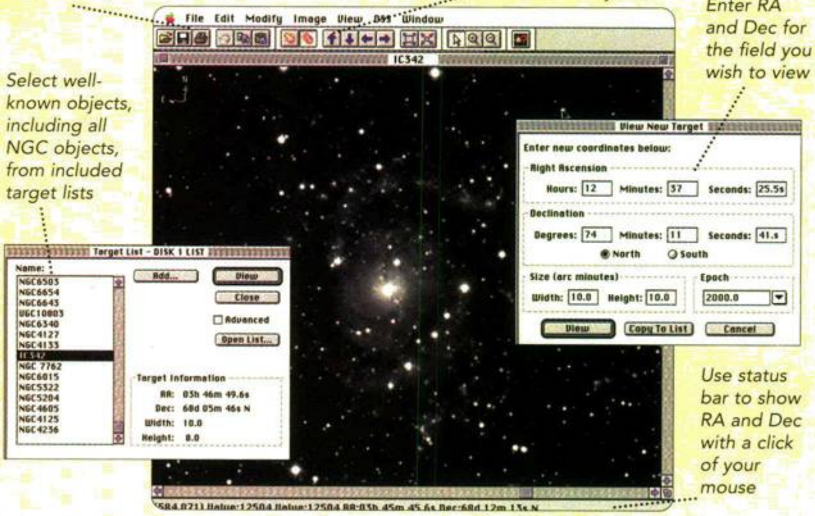

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NGC6643
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NGC6340
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NGC6015
NGC5322
NGC5204
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RA: 03h 46m 49.6s
Dec: 68d 05m 46s N
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Height: 0.0

View New Target

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Degrees: 74 Minutes: 11 Seconds: 41.s
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MARS GLOBAL SURVEYOR

An Ancient Martian Lake Bed?

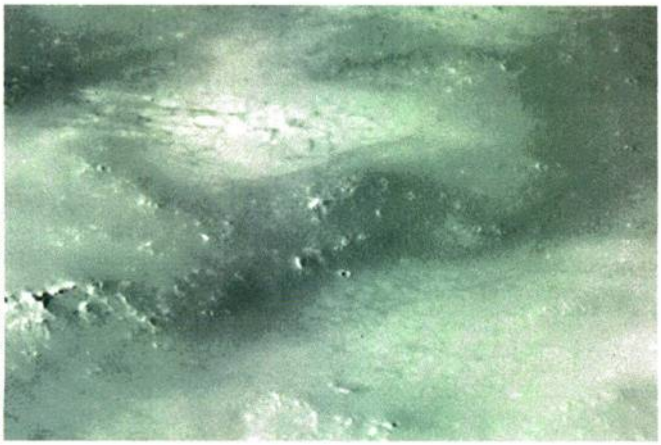
Mars Global Surveyor remains in an elliptical orbit, periodically dipping into the upper atmosphere to aerobrake into a circular mapping orbit. The elliptical orbit will continue for most of 1998. This is bad from the point of view that much of the time is spent far from the planet, but it is good in the sense that the low point in the orbit is much closer to Mars than the originally planned 248-mile-high (400 km) mapping mission. So during closest approaches, the three main instruments can take high-resolution images, spectra, and altimetry data from very low altitudes.

Targeting Mars features is on a catch-as-catch-can basis. One of the broad goals, however, is to look for signs of ancient lakes or seas. These might be found in the form of playas, or dry lake beds. When water runs across the surface of a desert, it typically dissolves salts, sulfur compounds, carbonates, and other minerals from the soil. If standing water in low areas evaporates, these compounds are concentrated and left behind in the soil as whitish deposits (like carbonate bathtub rings). Playas are thus often seen as bright, flat deposits. Numerous examples can be found in the desert valleys of the western U.S., including the Wilcox playa in southeastern Arizona, easily seen by airplane passengers.

If there were ancient seas or lakes, playas may have formed as Mars's

(see "Mars," p. 26)

Evidence of an ancient martian lake bed? Some researchers suggest the whitish area at the upper left represents playa deposits, left by evaporating water. The width of the image is about 1.8 miles (2.9 km).



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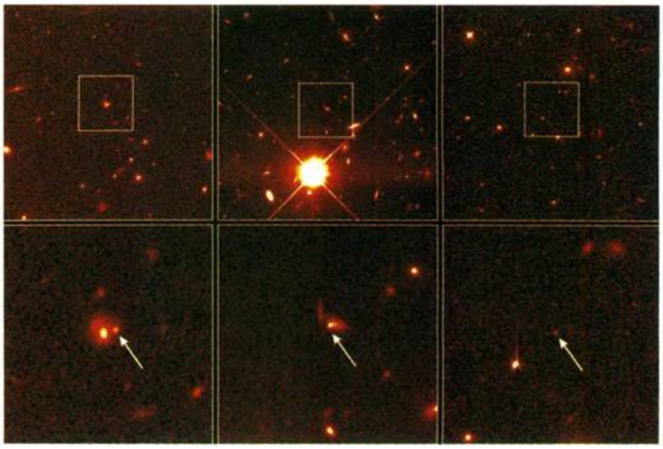


Peter Garnavich (CfA), the High-z Supernova Search Team, and NASA

Hubble made these portraits of some of the most distant supernovae ever seen — all lie at least five billion light-years from Earth. By analyzing the light from these cataclysmic stellar explosions, astronomers have concluded that the expansion of the universe should continue forever.

COSMOLOGY

Universe Should Expand Forever

Will the universe expand forever, or will it stop one day and then begin contracting? Several recent studies strongly suggest that the universe will continue expanding and may in fact pick up speed over time.

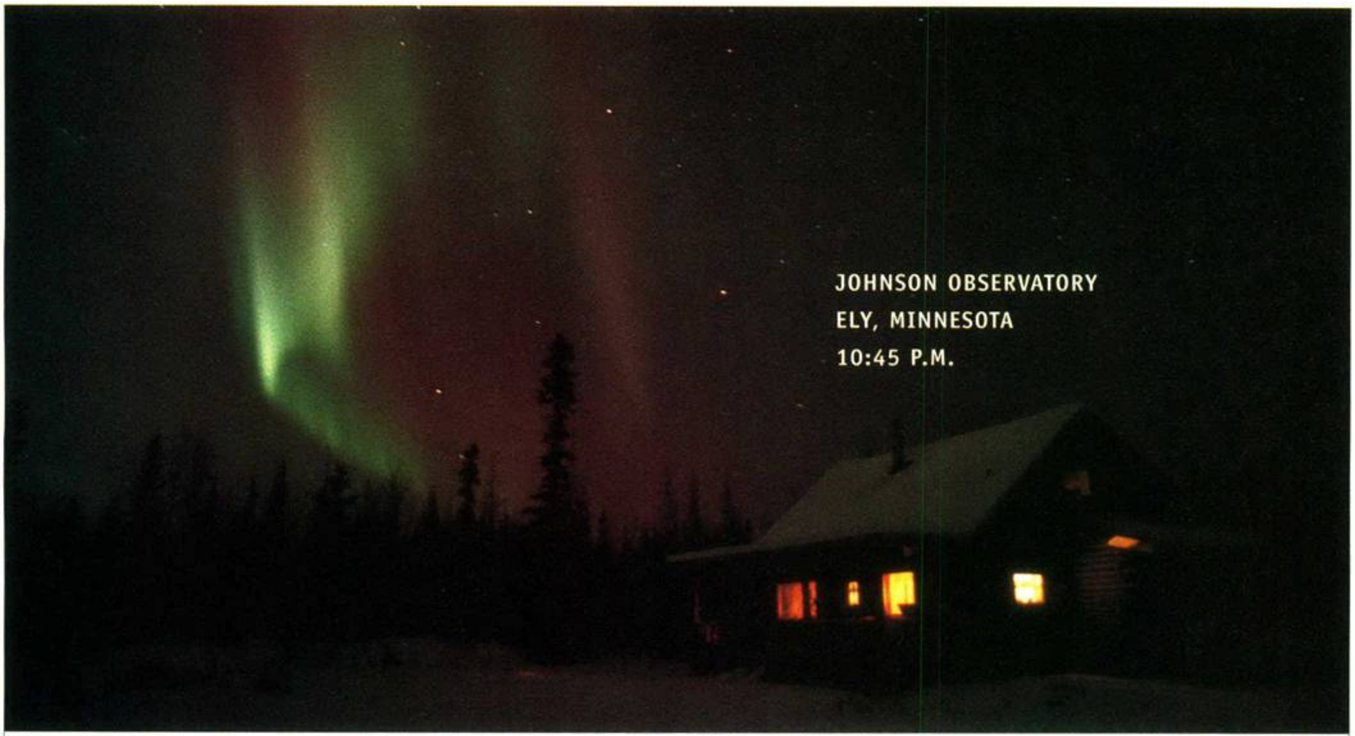
In the first two studies, astronomers used large ground-based telescopes and the Hubble Space Telescope to examine several Type Ia supernovae in the distant universe. Type Ia supernovae arise when a white dwarf star collects enough matter from a companion star to push it above 1.4 solar masses. No longer able to support itself, the white dwarf collapses and explodes.

Because all Type Ia supernovae form under similar conditions, they show remarkably similar behavior, allowing astronomers to readily compare nearby supernovae with far more distant ones. And they are so bright that they can be seen halfway across the universe.

Groups led by Saul Perlmutter of the Lawrence Berkeley National Laboratory and Peter Garnavich of the Harvard-Smithsonian Center for Astrophysics plot the apparent brightnesses of a number of these supernovae against their distances. The plots show whether or not the expansion rate has changed significantly during the history of the universe. The groups have now studied several dozen distant supernovae, and the trend is clear: "All the indications from our observations are that we live in a universe that will expand forever," says Perlmutter. Garnavich adds that his team is "95 percent confident that the density of matter is insufficient to halt the expansion."

Two other research teams have reached the same conclusion using different techniques. Neta Bahcall of Princeton University and her colleagues are looking at how many massive galaxy clusters exist in the distant

(see "Universe," p. 26)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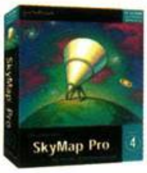
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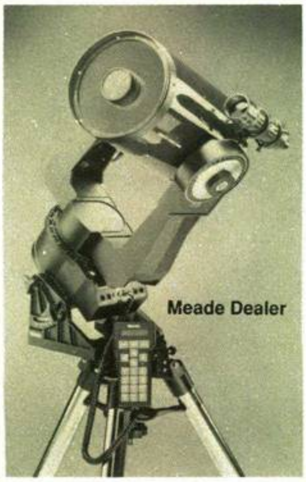
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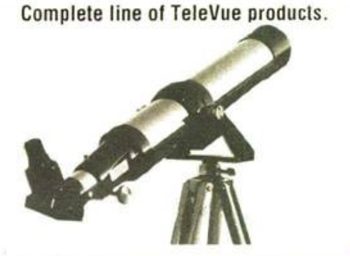

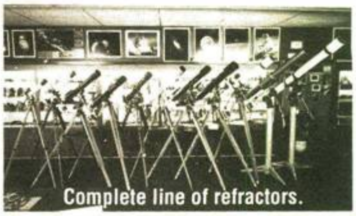
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(Mars)

surface dried out. Drifting dust may cover most of them. But drifting dust may occasionally exhume them too.

A Mars Global Surveyor photograph radioed back in the fall of 1997 shows an unusual whitish patch about 0.6 mile (1.0 km) wide, which seems to be centered in a low, flat area of sediments. The bright surface is crossed with dark lines, reminiscent of crack patterns in desiccated desert playas. This feature might be one of the long-sought lake bed deposits. Alternatively, the crack-like lines might be produced by freeze-thaw cycles of ice-saturated soil — also a possible sign that water ponded in this area.

— WILLIAM K. HARTMANN, PLANETARY SCIENCE INSTITUTE

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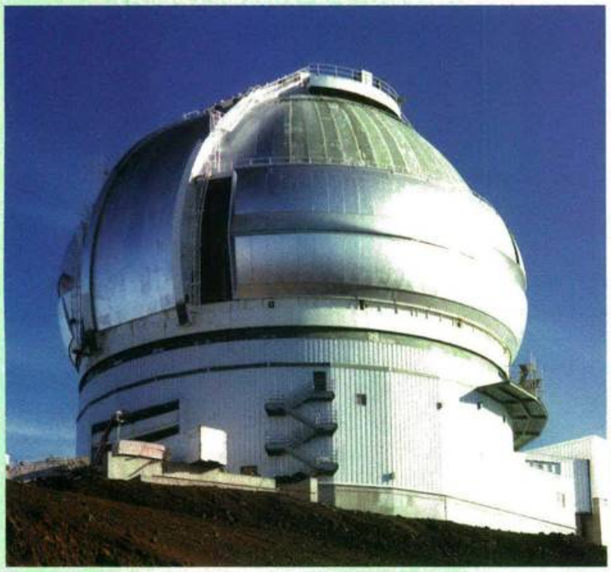

Gemini 8-meter Telescopes Project

THE TWINS MOVE FORWARD **The 8-meter Gemini Telescope atop Hawaii's Mauna Kea (above) is on schedule to achieve first light in December 1998. The Gemini project will place two identical 8-meter telescopes at prime observing sites: on 13,780-foot (4,200 meters) Mauna Kea and on 8,907-foot (2,715 meters) Cerro Pachon in central Chile. Construction of the Gemini North Base Facility at Hilo, Hawaii, began last August and should be completed within a year. Construction at the Mauna Kea site is also in full swing. The mirror's coating chamber was transported to the summit last August as was the telescope's structure. The South Telescope site at Cerro Pachon has not been as lucky. Though construction is under way, severe winter storms and a 6.8-magnitude earthquake last October caused delays and damaged the road to the site. The Gemini Project is an international effort to provide complete sky coverage under the best possible observing conditions.**

(Universe)

universe. In a high-density universe — one that might one day stop expanding — most massive clusters would form in relatively recent times. In fact, the odds are about 1,000 to one against even a single massive cluster forming at a time halfway back to the Big Bang. But Bahcall has found three massive clusters, implying that the universe has only 20 percent of the matter needed to halt the expansion.

A group led by Ruth Daly, also of Princeton University, looks at radio galaxies to reach the same conclusion. The apparent size of these enormous galaxies depends on the geometry of the universe as a whole, which in turn determines the universe's ultimate fate. A relatively small size at great distance would suggest a universe that will recollapse, a larger size implies a universe that will continue expanding but at an ever-decreasing rate, and an even larger size suggests a universe that will expand forever at an accelerating rate.

Surprisingly, Daly and her colleagues find that the distant radio galaxies appear huge, supporting eternal expansion and, at this stage at least, hinting that the universe will expand faster in the future. This implies some sort of "anti-gravity" force — the famed cosmological constant introduced by Albert Einstein in his general theory of relativity. Perlmutter's group also reaches this conclusion, although the results are still preliminary. If these findings are strengthened and confirmed, it would turn what Einstein called his "greatest scientific blunder" into a remarkable prediction.

BLACK HOLES

Cosmic Old Faithful

▶ Astronomers have found that some of the matter spiraling into a massive black hole in our galaxy escapes its dark fate by erupting into twin jets traveling at nearly the speed of light. Although the jets had been seen before (see "A Black Hole Erupts," March 1998), this is the first time they have been directly linked to material falling into the black hole.

The object, known as GRS 1915+105, lies about 40,000 light-years away in Aquila. First detected in 1992, it consists of a black hole weighing between 10 and 30 solar masses and a companion star in orbit around it. The black hole pulls material from the companion, which forms an accretion disk around the black hole. Friction in the disk heats the gas to millions of degrees, causing it to shine brightly in x rays.

Two research teams, one led by Ronald Remillard of MIT and the other by Jean Swank of NASA's Goddard Space Flight Center, observed x rays from GRS 1915+105 with the Rossi X-ray Timing Explorer satellite. They found that the x-ray emission drops dramatically every 30 minutes or so. "Since the x rays come from the parts of the disk closest to the black hole," says Remillard, "when we saw the x-ray dips every half hour it seemed that the inner disk was disappearing."

What happens to the inner disk? Stephen Eikenberry of Caltech and his

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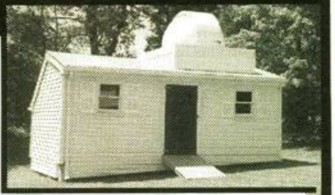

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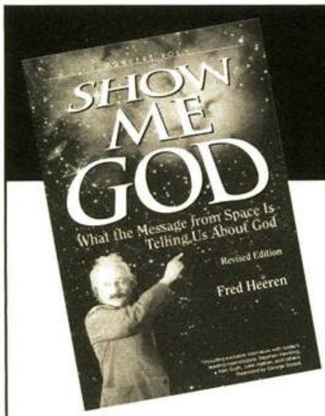

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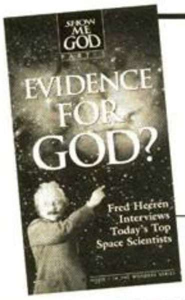

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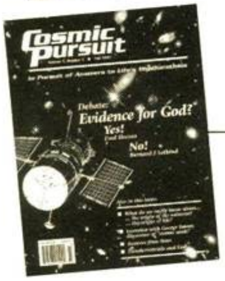

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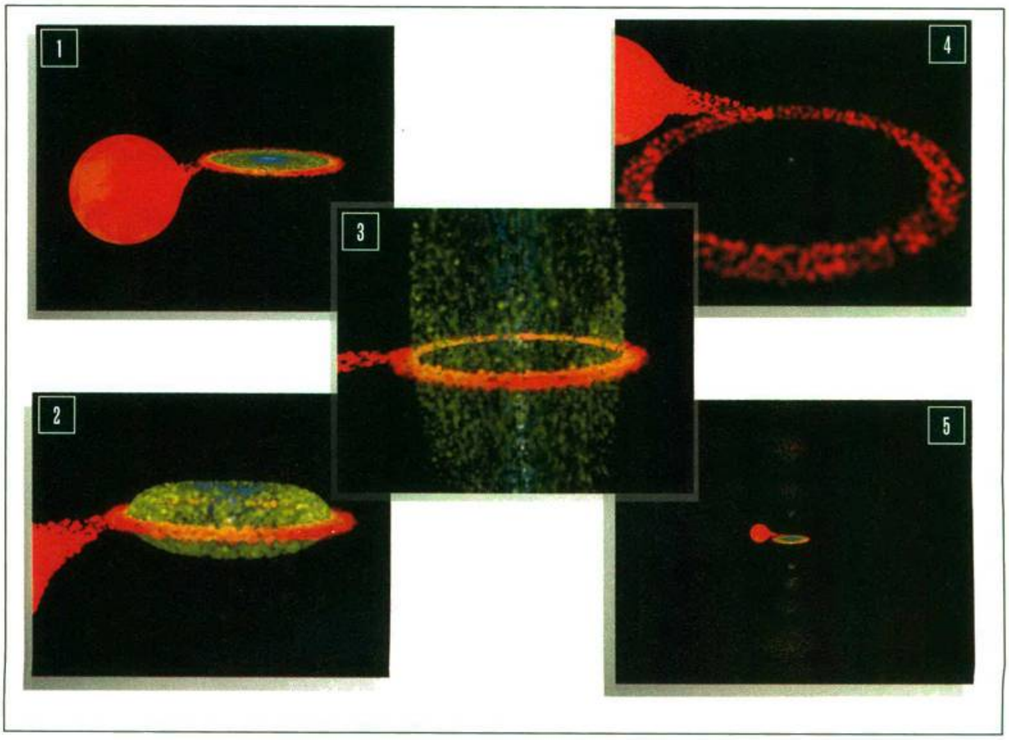
colleagues observed GRS 1915+105 with the 200-inch Hale Telescope on Palomar Mountain and found that the system flares up in the infrared right when the x-ray emission drops. Apparently the matter gets funneled into twin jets, which escape from the black hole's vicinity at 92 percent the speed of light. While the system behaves like a celestial counterpart of the Old Faithful geyser, it is far more powerful: Every half hour an asteroid's worth of material gets ejected at near light speed — representing six trillion times the energy used by the United States in a year.



NASA

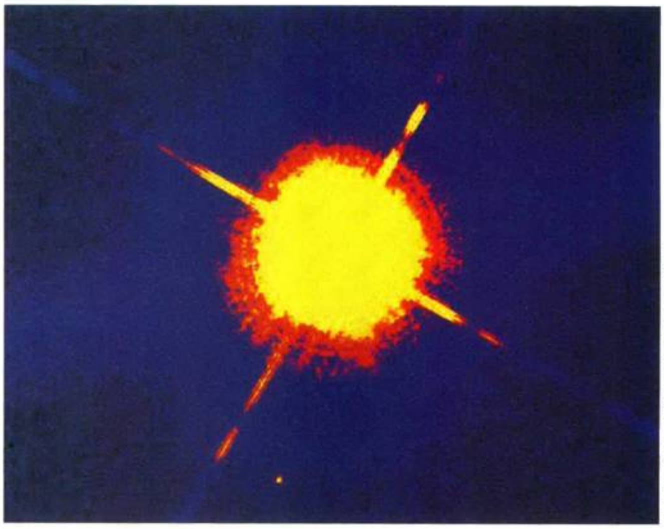
In this computer simulation of GRS 1915+105, the black hole's gravity pulls in material from a companion star, forming an accretion disk (1). Once a critical mass is reached (2), the inner part of the disk is ejected into twin jets (3), clearing the inner region (4). The process then starts anew (5), repeating itself every 30 minutes.

"Many models have predicted that jets are linked to the inner accretion disk," says Eikenberry. "However, the direct connection between the disappearance of the inner disk and the jet ejection has never been seen until now."

GALACTIC ASTRONOMY

Brown Dwarfs Galore

▶ Just three years ago, astronomers were wondering "Where are the brown dwarfs?" They suspected these "failed stars" existed in large numbers, but they didn't have proof. Thanks to improved instruments, astronomers have now found so many that brown dwarf researcher Mark Marley of New Mexico State University says he has "lost count."



Shrinivas Kulkarni (Caltech), et al., and NASA

Brown dwarf Gliese 229B is the tiny dot at the bottom. Its companion star, Gliese 229A, is the overexposed blob in the center.

Astronomers have focused much of their attention on Gliese 229B, which was discovered in 1995. At a distance of 19 light-years, it is the closest known brown dwarf. Gliese 229B's outer layers are only 1160° F (900 kelvins), making it the coolest (and oldest) brown dwarf discovered to date. Astronomers have detected a variety of molecules in GL229B's spectrum, including water and methane, meaning the chemical composition of its outer atmosphere is similar to Jupiter's.

Marley and his colleagues Keith Noll of the Space Telescope Science Institute and Tom Geballe of the Joint Astronomy Centre in Hawaii recently detected carbon monoxide in GL229B's spectrum. This was mildly surprising, because carbon monoxide should not exist in the cool outer layers of GL229B. Marley and his colleagues think carbon monoxide is being dredged up from warmer layers below by convection, the same process that causes bubbles to rise in a pot of boiling water. "We're trying to do the meteorology of this object, which is in between a star and a planet," says Marley. "By tracing convection we're starting to understand atmospheres and mixing and all of the kinds of things we've studied in the planets of our own solar system."

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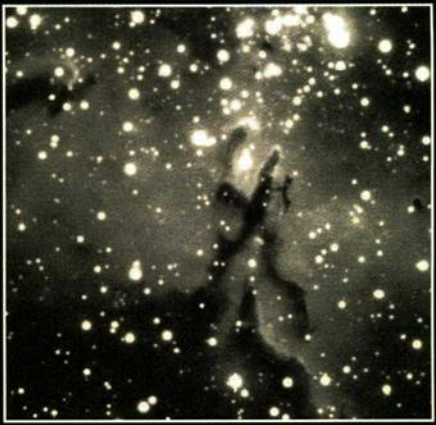

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STELLAR ASTRONOMY

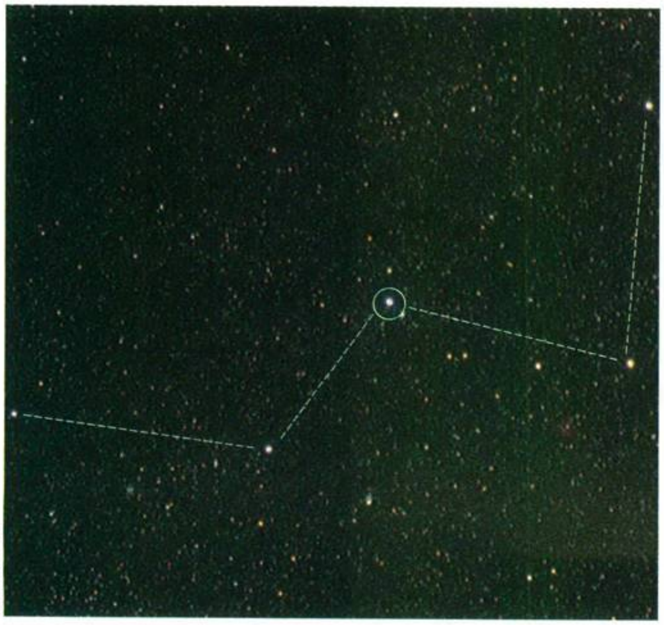
A New Class of X-ray Stars?

▶It took 20 years and two space telescopes working in tandem, but astronomers may have found the solution to a baffling puzzle — and discovered a new class of x-ray star in the process. For 20 years, astronomers have known that there are powerful, variable x rays streaming from Gamma Cassiopeiae, a second-magnitude star 600 light-years away — but the reason for these emissions has remained an enigma.

Gamma Cassiopeiae belongs to a class of hot, massive stars known as "B-emission," or "Be" stars. But all Be stars except Gamma Cassiopeiae show faint x-ray emission. Astronomers thought Gamma Cassiopeiae's unusual x-ray behavior could be explained by the infall of gas onto a dense companion star, but repeated searches have found no such companion.

To understand the origin of these x rays, Myron Smith of the Space Telescope Science Institute and colleagues pointed both the Hubble Space Telescope and the Rossi X-ray Timing Explorer at the hot star for one full day in March 1996. The surprising discovery? The simultaneous observations showed that the slower x-ray variability in Gamma Cassiopeiae is consistent with variations in its ultraviolet emission, leading the team to believe that the x rays must originate from the star's surface. The x rays are probably produced by extraordinarily hot surface flares (100 million kelvins), ten times hotter than those ejected by our sun.

The finding suggests that Gamma Cassiopeiae may be the first member of an entirely new class of variable x-ray stars. As Smith puts it, "There is no such thing as uniqueness in astronomy. Where there is one peculiar star, there are many more somewhere else."



Gamma Cassiopeiae (circled) is the bright middle star of the constellation's famous W.

John Chumack

AXAF Launch Delayed

NASA has been forced to postpone the scheduled August 27 launch of the $2-billion Advanced X-ray Astrophysics Facility (AXAF) due to delays at TRW Inc., the prime contractor for the satellite. The launch has been rescheduled for December 3. The delay will add $40 million to the cost of the mission.

Hubble Gets New Director

The Space Telescope Science Institute will soon have a new leader. Subject to final contract approval, Steven Beckwith will become director of the institute on September 1, 1998. He is a former member of the astronomy faculty at Cornell University and is currently the managing director of the Max-Planck-Institute for Astronomy in Heidelberg, Germany. Beckwith will replace Robert Williams, who elected to step down after a five-year term.

Space Telescope Science Institute

Steven Beckwith will become the Hubble Space Telescope's main man on September 1, 1998.

Mars Munchies

When your stomach rumbles on Mars, and freeze-dried ice cream just won't do, what do you eat? With a three-year NASA grant, Cornell University researchers are working to develop recipes that astronauts can make from crops grown in future space habitats — in preparation for multi-year missions to the moon and Mars. The staples, wheat and potatoes, will be complemented by rice, soy, peanuts, salad crops, and herbs. Brave taste-testing panels composed of students, faculty, and staff feast weekly on everything from tempeh Sloppy Joes to tofu cheesecake. According to one participant, "It's as good as food at a four-star restaurant."

A Pulsar Spins into History

Frank Marshall of NASA's Goddard Space Flight Center and colleagues have discovered a young pulsar spinning more than 60 times a second, making it the fastest such pulsar known. Born in a supernova explosion some 4,000 years ago, the pulsar spins about twice as fast as the previous record holder, which lies at the heart of the Crab Nebula in Taurus. (Astronomers have discovered a few millisecond pulsars, which spin hundreds of times per second, but they are all old objects that have been "spun up" through interactions with a companion star.) The record-setting pulsar lies in supernova remnant N157B in the Large Magellanic Cloud and was discovered with the Rossi X-ray Timing Explorer satellite.

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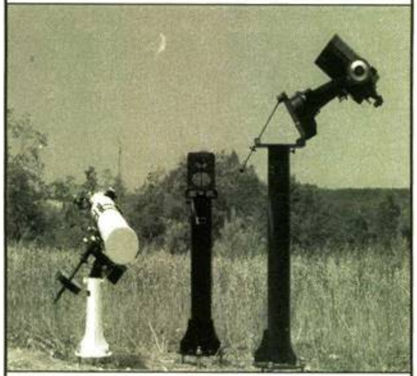

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STELLAR EVOLUTION

Eta Carinae May Have a Binary Companion

▶ If David Letterman ever wanted to draw up a Top Ten list of the most awesome stars in the Milky Way Galaxy, Eta Carinae would surely make the cut. Pumping out energy at a rate of five million suns and weighing in with 50 to 100 solar masses, the blue supergiant is one of the most massive and violent stars known to science (see "Angry Giants of the Universe," October, 1997).

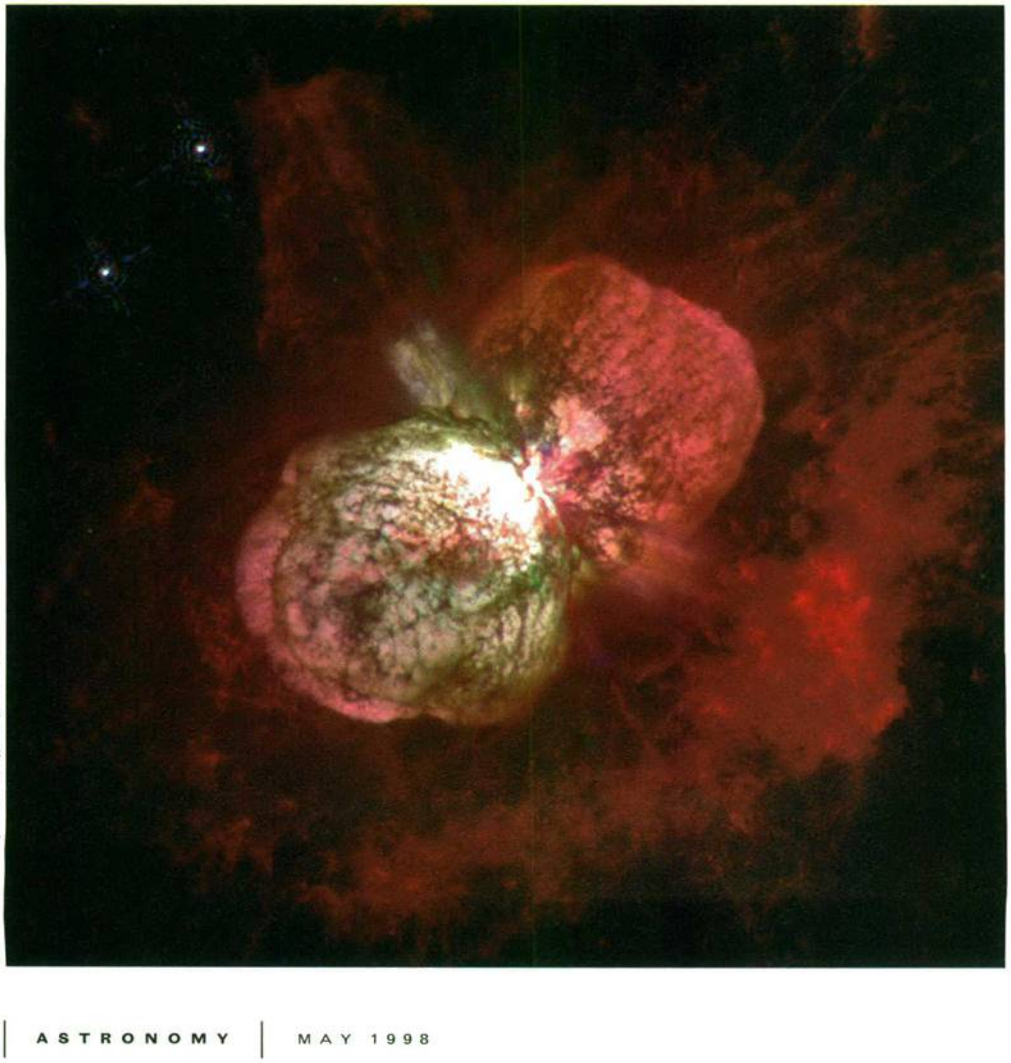
New observations lend credence to the idea that a companion star might bear the brunt of Eta Carinae's fury. Augusto Damineli of the University of São Paulo in Brazil has previously reported periodic 5.5-year variations in Eta Carinae's near-infrared and optical spectra that he attributes to a massive binary companion. In Damineli's model, Eta Carinae consists of two stars in a 5.5-year elongated orbit. In December 1997, when Damineli predicted the two stars would come closest together, Eta Carinae began repeating the spectral cycle that started 5.5 years ago. "The event arrived on schedule, as predicted," notes Damineli.

Observations by NASA's Rossi X-ray Timing Explorer (RXTE) satellite lend support to Damineli's binary model. Throughout 1997, a team led by Michael Corcoran of the Universities Space Research Association was using RXTE to measure the gradually increasing x-ray flux from Eta Carinae. According to Corcoran, as the stars get closer and closer, their stellar winds slam together, creating a shock wave that heats the gas to about 60 million degrees. Gas at this searing temperature will emit torrents of x rays. When the stars move apart, the shock wave weakens, reducing the production of x rays.

But in December 1997, RXTE showed that Eta Carinae's x-ray emission came to a screeching halt. "The x-ray brightness plot looked like a stock market chart leading up to a crash," says Kris Davidson of the University of Minnesota. The observations suggest that a thick disk of material along our line of sight was blocking the x rays so they couldn't reach Earth. In a model developed by Davidson and his Minnesota colleague Kazunori Ishibashi, the smaller star passes through Eta Carinae's dense equatorial disk at closest approach, which screens the x rays from view.

Davidson acknowledges that while the binary model is gaining acceptance among astronomers, "There is still a pretty good chance that it is wrong." For example, the RXTE observations also reveal an 85-day periodicity that remains unexplained. "I'm afraid that Eta Carinae is turning out to be more complex than any other famous stellar object known," he says. 🅰

This Hubble Space Telescope image shows the powerful blue supergiant star Eta Carinae embedded in two lobes of gas ejected in a giant flare-up seen in the 1830s and 1840s.



Jon Morse (University of Colorado), et al., and NASA

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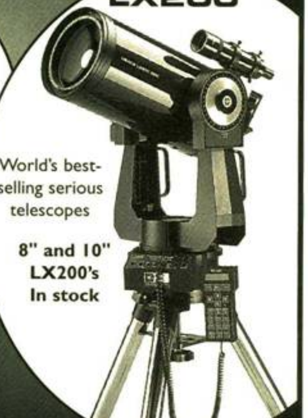

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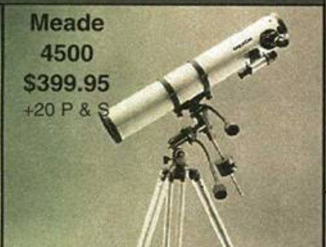

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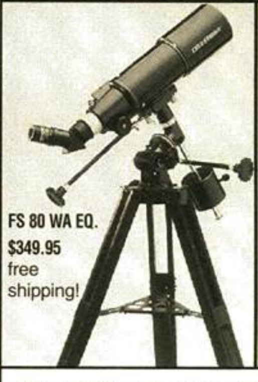

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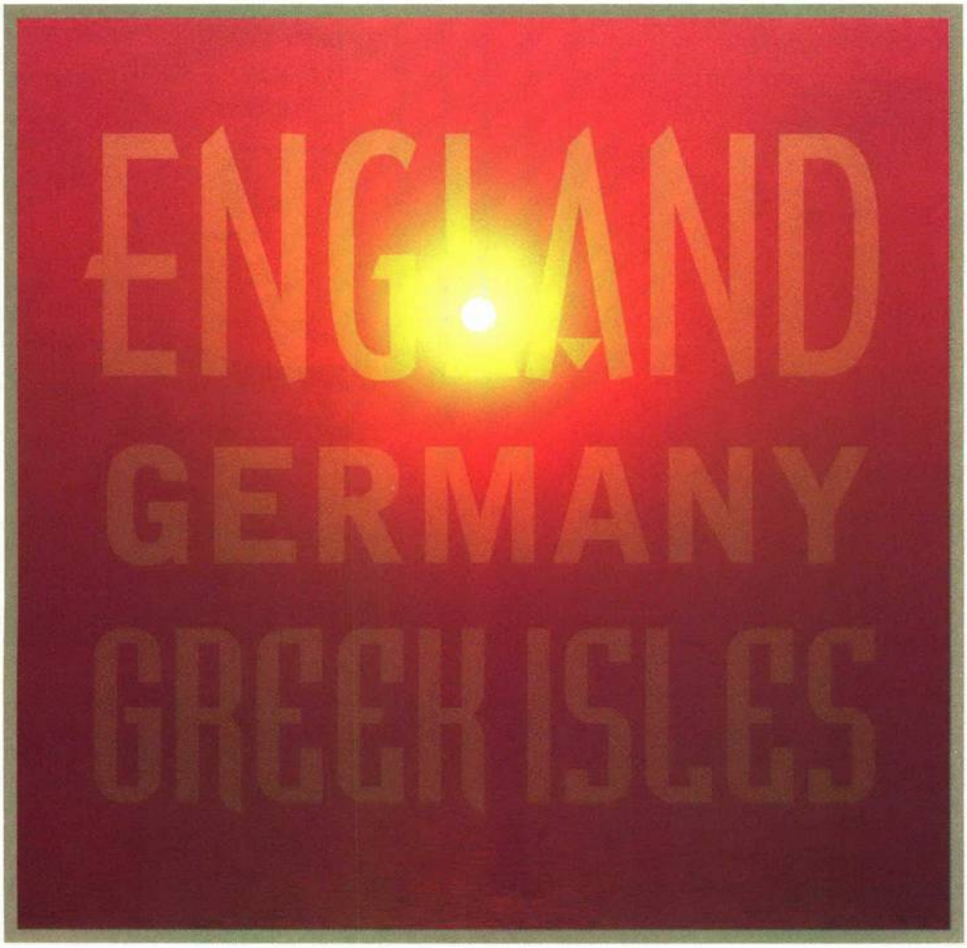

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USGS

Making an Exceptional I·M·P·A·C·T

A self-described "rock-knocking geologist," planetary scientist Eugene Shoemaker showed that Earth and the rest of the solar system were prone to violent impacts.

by Rex Graham

David Roddy (Lunar and Planetary Institute)

Nearly a mile across, Meteor Crater shows what can happen when a 300,000-ton rock strikes Earth (above). The Shoemakers discovered more than 30 comets with the Palomar Schmidt telescope (left).

Carolyn Shoemaker said it was an ironic tragedy: Her husband, whose work had been summed up a few months earlier in a National Geographic TV documentary, "Asteroids: Deadly Impact," himself died in modern society's most deadly type of collision. On July 18, 1997, Carolyn Shoemaker and her husband, Gene, were driving a pickup on a gravel road 310 miles north of Alice Springs, Australia, to study an ancient impact crater. Motorists traveling in either direction use the smooth center of the road when there is no approaching traffic. They drive fast enough to dampen the shaking effect on their vehicles of the road's washboard surface.

"We were rounding a bend. There were acacia bushes on both sides," said Carolyn, who suffered five fractured ribs, a broken wrist, a dislocated shoulder, and other injuries in the accident. "Suddenly this other vehicle, a Land Cruiser, appeared directly in front of us. . . . It was instantaneous — no time to be worried or afraid or avoid it." Her husband, geologist Eugene M. Shoemaker, died of injuries in the head-on collision. He was 69.

No time to avoid it. Shoemaker feared that might be modern civilization's fate. He was a scientific Chicken Little who looked down as well as up. As a geologist who helped prove the impact origin of Meteor Crater in Arizona and other craters, he showed that the sky had indeed fallen before. Collaborating with Carolyn and other astronomers, Shoemaker looked for planet-crossing asteroids and comets. "He did an incredible service to science, alerting the world to the trajectories of Earth-crossing asteroids," said W. Gary Ernst, a Stanford University geologist. "Their frequency has tailed off considerably, but Gene, more than any other scientist, has documented the likelihood of additional impacts. He's done the Lord's work, and he is an absolutely incredible guy."

A Geologist at Heart

Shoemaker called himself a "rock-knocking geologist," whose most important tools were telescopes. He founded, with astronomer Eleanor Helin, the Palomar Planet-Crossing Asteroid Survey in 1973 at Caltech. He helped determine the cratering rate of the moon and ingeniously estimated the ages of many of its geologic features. He recommended to NASA where the Apollo astronauts should land and provided expert commentary, seated at the elbow of CBS News anchor Walter Cronkite, when the astronauts landed.

In 1983, Shoemaker established a second asteroid survey with his wife Carolyn, who became a premier astronomer in her own right, and amateur astronomer David Levy. The world was riveted by the 1994 collision of Comet Shoemaker-Levy 9 with Jupiter. That impact seemed to support Shoemaker's controversial view that Earth's own impact rate had doubled during the past 200 million years. The doomsday quality of his predictions was reflected in "Asteroids: Deadly Impact." He also was quick with a smile and a joke: His friends and colleagues could quickly locate him in a crowded room by listening for his frequent bursts of laughter. Not only was Shoemaker the father of astrogeology and an articulate translator of science to the general public, he arguably was this century's greatest planetary scientist.

Not the Retiring Type

I visited Shoemaker one day last May in his U. S. Geological Survey office in Flagstaff, Arizona. He had officially retired four years earlier, but continued with the USGS on emeritus status. His office was a cluttered testament to his 45-year career. Desks were stacked with notebooks, reports, and books. Tables were strewn with a few of the many meteorites and awards he had collected. Pink message slips were scattered around a phone like fallen maple leaves. The wastebaskets were empty. At one point during my visit, David Rodrigues, a talkative amateur astronomer visiting from San Leandro, California, walked in and ad-libbed questions during the interview.

"Gene, what does your jovian-cratering model imply for the age of Europa?" Rodrigues asked. With only one large crater, a 16-mile-wide divot in the jovian moon's icy crust, the surface appears much younger than those of Europa's sister moons, Ganymede and Callisto. If Europa was as old as its siblings, it would be expected to have many more craters.

"Well, you do the cratering count and it suggests it's 10 million years old," Shoemaker said. "But let's face it, it's (geologically) active. . . ."

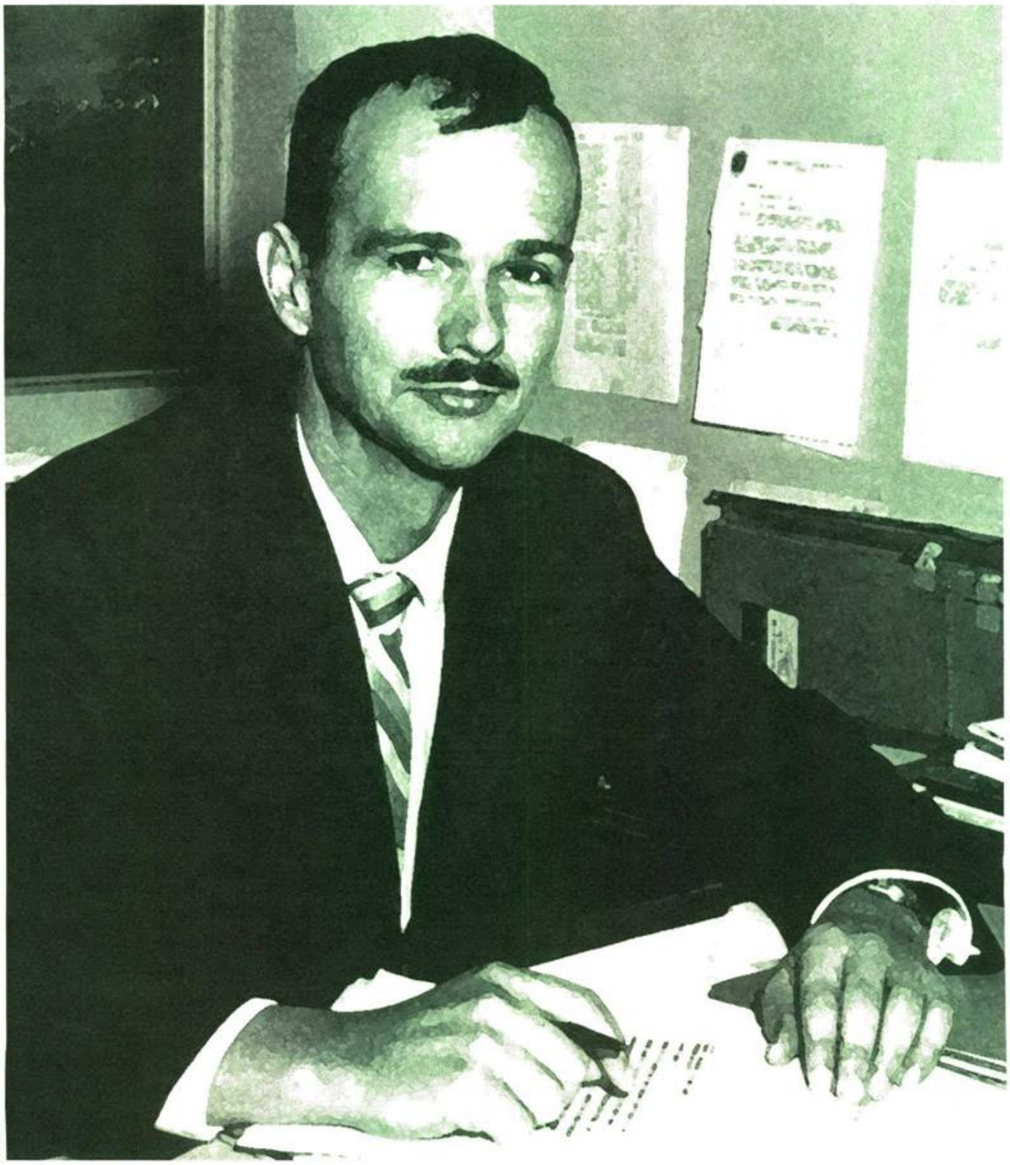
"Do you have a reprint of your April '97 cratering-rate article?" I asked.

"Sure," Shoemaker said and then paused. He remembered where he had put the reprints, pivoted and knelt in front of a metal filing cabinet. Looking up, he described to Rodrigues and me his upcoming trip to Australia. Frustrated with a balky file-cabinet drawer, Shoemaker yanked its handle and somehow cut an index finger. It was a deep scratch and blood trickled from it. Rodrigues, who didn't immediately see the blood, switched from Europa to Australia: "Given its surface area," he continued, "what are the chances of Australia getting hit?"

Shoemaker explained that the answer would depend on how large an impact would be considered "a hit," when, in geologic time, such an impact would occur, and other factors that would complicate a simple answer.

As Shoemaker stood up, dabbing the bloody digit with a tissue, Rodrigues fired again: "Well, Gene, given the surface area of Gene Shoemaker, what is the probability you'll get hit while out in Australia?"

A mischievous smile spread across Shoemaker's suddenly delighted face. His arms, with the bloody tissue extending from one hand, shot up like a football referee's touchdown signal. "Whoa," he roared, laughing riotously. "That would be the way to go! 'Shoemaker Killed by a Meteor'. . . That would be great! That's the way I want to go."



USGS

In the mid-1960s, Shoemaker *headed the U. S. Geological* Survey's Branch of Astrogeology, which he conceived in 1961.

Shoemaker was born in 1928 in Los Angeles, California, and spent his early childhood in Buffalo, New York, where his mother took a job as critic teacher at Buffalo State Teachers College. Jobs were scarce during the Depression, and Shoemaker's father was forced to work as a physical education instructor at Civilian Conservation Corps camps in Wyoming. While he was still in elementary school, Shoemaker was permitted to attend evening classes for high school students at the Buffalo Museum of Science.

He loved rocks and geology. During the family's summer get-togethers out West, Shoemaker gathered North Platte River stones from the unpaved streets. "I'd spend hours and hours smashing the rocks; just throwing them down," he said. "Later, I really got into minerals and gemstones." His apprenticeship as a lapidary during high school was reflected in his choice of bolos, or string ties, for his formal neckwear. (He wore a silver and turquoise bolo when he received the Presidential Medal of Science in 1992 from President Bush.)

Shoemaker's parents moved to Los Angeles and his father became a grip in the Goldwyn studios in Hollywood. Young Shoemaker, always in a rush to learn, completed high school in two years. In 1944, at age 16, he enrolled at Caltech. Many of his fellow Caltech students were older, gung-ho Navy officers eager for combat, but the underage freshman was equally revved up. Caltech's tradition of academic competition allowed Shoemaker to pit himself intellectually against the older students. He excelled, earning a bachelor's degree in geology in less than three years. He earned a master's degree a year later. "I learned, scientifically, what geology was all about. I blossomed," he said. "I learned how to discover the geological structure of a place."

Barely 20 years old, Shoemaker took a job as a geologist with the USGS and trekked the West. He sometimes lived out of a tent while mapping the mineral resources of the Colorado Plateau region, a surreal landscape of mesas and canyons. Between USGS projects, Shoemaker did graduate work at Princeton University, where he earned his Ph.D. He returned to the West and to the USGS. "I loved being out in the field," he said. (He was known, years later, for his goat-like agility to scramble up the walls of canyons. "I went to Meteor Crater with Gene. He is a great geologist," said Brian Marsden, a Harvard University astronomer and director of the Central Bureau for Astronomical Telegrams in Cambridge, Massachusetts, the organization that names comets. Said George Wetherill, a geophysicist and astronomer at the Carnegie Institution of Washington: "I couldn't keep up with him.")

Shoemaker's first major geologic discovery at Meteor Crater — with USGS colleague Edward Chao — was coesite, a form of silica that could only be transformed from quartz by the pressure of an extraterrestrial impact. Shoemaker also documented the fiddle-headed curling at the lip of the crater's otherwise horizontally banded rock. The curling, the coesite, and asteroid fragments littering the site and buried under the crater proved its impact origin. Shoemaker said it was logical to become interested in the other planets' pocked peripheries. At the time, however, most astronomers were eager to use the increasingly more powerful telescopes that were being made to study star formation, the expansion of the universe, and other more distant fundamental processes. Planetary science was passé.

Dreaming of the Moon

The Soviets became a bonus for Shoemaker when they launched the first Sputnik satellite in 1957. The United States was committed to beat its archenemy to the moon. Shoemaker conceived of the USGS's Branch of Astrogeology in 1961 and was named to head it. In the process, he fashioned himself as a human rocket aimed at the door of NASA's Apollo program. "When the time came to choose scientists for the crew, I wanted to be at the head of the line," he said. "I wanted to be the most qualified."

STScI/NASA

Like pearls on a string, more than a dozen fragments of Comet Shoemaker-Levy 9 lie poised to strike Jupiter in 1994.

He probably was — at least until 1962. That was when he suddenly lost weight, suffered abdominal pains, and developed a deficiency of oxygen-carrying red blood cells. He was diagnosed with Addison's disease, a rare failure of the adrenal glands to produce enough steroid hormones. Doctors successfully treated the disease with daily steroid pills that Shoemaker took the rest of his life, but the ailment disqualified him from becoming an astronaut. "I was disappointed I'd never get to the moon myself," Shoemaker said.

He shared his disappointment with his wife, and few others. Gene had met Carolyn Spellmann, the sister of his Caltech roommate, in 1950. They married a year later while he was a Princeton graduate student. "I loved his enthusiasm for life," Carolyn said last spring before the trip to Australia. "As he describes anything, he gets very excited and he likes to know everything about it. His enthusiasm makes me enthusiastic." After her marriage, Carolyn quit her job as a teacher and devoted the years between 1952 and 1983 to raising her three children.

After her children were grown, Carolyn, who had a master's degree from Chico (CA) State College in history and political science, launched a new career. She learned from Gene's colleague and former student Schelte "Bobby" Bus how to photograph the night sky with the 18-inch Schmidt telescope at Palomar Mountain. Together, she and Gene, often helped by others, took 8- to 10-minute exposures of a 60-square-degree piece of sky, an area about 300 times that of the full moon. They photographed the same piece of sky an hour or so later. Between 40 and 80 pairs were exposed on a good night. With this approach, they photographed up to 10 percent of the sky in a week's observing run.

A Comet-Hunting Triumvirate

The method was vastly more efficient than semi-randomly scrutinizing the night sky through a telescope, straining to see the fuzzy coma and tail of a comet. The first great comet hunter, French astronomer Charles Messier, made his first comet discovery that way in 1759. Messier was credited with discovering 15 comets — all with simple reflecting telescopes. Like many dedicated comet hunters of his day and today, Messier became obsessed. "He almost considered them his own property," wrote John Mallas and Evered Kreimer, authors of *The Messier Album*. Messier's achievements abruptly ended after he walked into a French icehouse and didn't notice that it lacked a floor. He fell 25 feet, suffering multiple broken bones. He never fully recovered.

Carolyn became arguably the best in the business at the most crucial step of the comet- and asteroid-hunting process — scanning pairs of negatives at the same time with a special stereoscopic microscope. The viewer's brain automatically aligns the millions of black stellar dots in the pair. In this technique, stars appear stationary. However, the relative motion of an asteroid or comet gives it a slight double-vision or "floating" effect when viewed with the microscope. Often, weeks of tedious scanning revealed lots of ordinary asteroids floating in orbits between Mars and Jupiter, but no planet-crossers.

David Levy, an amateur astronomer with a degree in English literature from Acadia University in Nova Scotia, Canada, was eager to join Gene and Carolyn. Levy had already discovered five comets on his own when he met Gene, his idol, in 1988 at an asteroid conference in Tucson. They worked together for five years.

One cold, windy night in 1991 at Palomar, strong winds continually rattled the telescope's outdoor shutter "leaves." The shaking would blur the images on the film during the 10-minute exposures and ruin the exposures in the process. So, while Levy tried to keep the telescope tracking on its target, Gene bounded like a gymnast up a moveable ladder inside the dome. From his dangerous perch, Shoemaker grasped the two rattling telescope leaves and held them to keep them from vibrating. Carolyn, who later emerged from the photographic darkroom, thought her high-wire husband had gone too far. "Is this really necessary?" she shouted at him. Later, she said she found a comet on that very film.

After totaling up the known comets and asteroids the Shoemaker-Levy team and other teams had discovered and after calculating the huge volume of space the objects occupied, Shoemaker and his colleagues made their long-awaited calculations. They were eager to know the chances that Earth will

USGS

The geologist in Shoemaker came out whenever he visited Meteor Crater. *In the mid-*1960s, he helped train future Apollo astronauts there.

sustain another catastrophic blow, like the impact 65 million years ago that many scientists think doomed the dinosaurs. Their estimate in the April 1997 paper in the *Journal of Geophysical Research* said that Earth's cratering rate during the most recent 200 million years was possibly double the rate of the previous 3 billion years. Their surprisingly high rate predicts a 10-kilometer crater on Earth every 100,000 years, a 20-kilometer crater every 400,000 years. They argue that the solar system's oscillations above and below the galactic plane have diminished. That shift, they argue, increased the tidal, or gravitational, perturbations on comets in the Oort cloud. The Oort cloud contains an enormous halo of very distant comets that extends almost halfway to the nearest star, Alpha Centauri. Any gravitational bump could nudge the objects' orbits just enough to turn them into planet-crossers.

An Impact in Earth's Future?

The Shoemaker team's estimate lacks the kind of precision Shoemaker had hoped for, partly because Earth's record of impact craters erodes relatively quickly and vanishes. That is one reason why the team's estimate of Earth's chances of being struck again has a margin of error of plus or minus 50 percent. At the greatest level of uncertainty, there has been no recent change in Earth's cratering rate. But Shoemaker was confident that the real margin of error is only 25 percent.

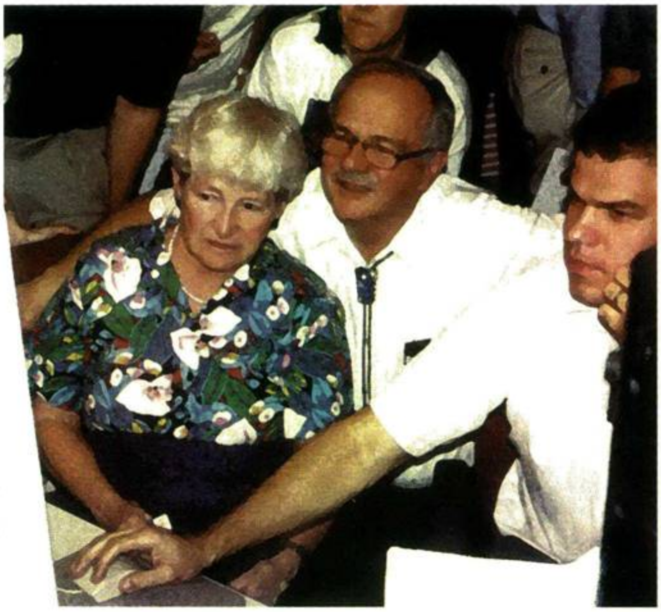
Not all planetary scientists bought Shoemaker's ideas, but they didn't dismiss them either. "Shoemaker was more optimistic than I am about how accurate his calculations were," said Wetherill. "He tended to make error estimates small, but that is not always a bad thing: There are people who err by always making the error estimates large, thereby missing real things. Even estimating the error has a large error in it."

The National Geographic Society took Shoemaker's estimates seriously after July 1994 when the roughly 20 fragments of Comet Shoemaker-Levy 9 bombarded Jupiter. The spectacle also rattled the collective public image of the solar system as a group of steady, unperturbable planets practically devoid of other objects, let alone millions of menacing objects. Maybe what Shoemaker had been saying for decades was right; maybe the sky was falling.

Carolyn herself has thus far discovered hundreds of asteroids and 32 comets, 27 of which she co-discovered with her husband. The 32 make Carolyn among the greatest comet discoverers of all time. She plans to resume her hunt for planet-crossing asteroids and comets this year at the Lowell Observatory in Flagstaff. Despite her feelings of sadness at the loss of her husband and colleague, she arranged Gene's memorial service in October to meet his often-expressed wishes that it be a celebration of a life well lived, not a mourning of his passing. A Flagstaff group, Men In Fedoras, played ragtime tunes before and after the memorial service outside Gene's office on the USGS lawn in Flagstaff.

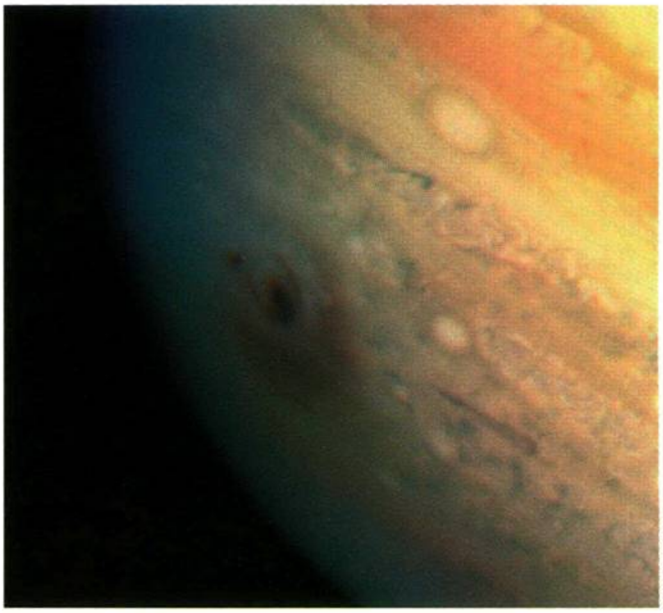
Apollo astronaut and geologist Harrison Schmitt eulogized his mentor as "a truly great scientist and visionary of our age, certainly. He would be anyone's first choice for a companion on an extended camping trip." The eyes of the 600 people gathered for the service often strayed from the speaker's podium to a huge color photograph of Gene. The enlargement captured Shoemaker in the midst of laughter. Several weeks later, Carolyn and her three children and their families scattered some of Gene's ashes from one of his favorite places — the south rim of Meteor Crater. And Gene's wish to make it to the moon will come true posthumously: A small portion of his ashes are aboard the Lunar Prospector spacecraft, which will impact the lunar surface when its mapping mission concludes in two to three years.

I asked Carolyn to reflect on her late husband, the accident, her grief, and her plans. Carolyn, subdued by her own sadness, guessed that her husband would have been grateful not to have survived with major disabilities from the accident. "For that I can be glad, for him," she said. Then she unexpectedly chuckled about the collision itself. "Gene would have said, 'Yes. Not bad at all. It would have been nicer had it come from a comet, instead of a different kind of impact.' " ■



John Aiello (STScI)

Gene and Carolyn watch as the first images of the Shoemaker-Levy 9 impact with Jupiter arrive at the Space Telescope Science Institute.



STScI/NASA

The impacts caused quite a stir on Jupiter too. The massive fragment G created a dark blemish larger than planet Earth.

Director Mimi Leder aligns Morgan Freeman.

This set recreates what we know about comets.

Deep Impact astronauts prepare for an excursion.

Astronauts attempt to destroy the comet.

CLOSE-UP OF A COMET CRASH

Deep Impact: A summer science-fiction action extravaganza explores humankind's reaction to an oncoming killer.

by Rex Graham

Movie Midas Steven Spielberg, the co-producers of *Jaws*, the director of television's *ER*, the special effects mastermind of *Jurassic Park*, and an all-star cast collaborated on what Paramount Pictures executives hope will be this summer's sci-fi box-office blockbuster. Instead of a 25-foot shark, this time the great white is a 500-billion-ton comet the size of lower Manhattan. Astronaut Spurgeon Tanner (portrayed by Robert Duvall) needs a lot more than a tank of compressed air to destroy the behemoth bearing down on us in *Deep Impact*.

Of course, the film is one of several summer sci-fi releases hoping to emerge as the *Air Force One* of 1998 at the box office. To achieve that, the creators of *Deep Impact* use a panel of distinguished scientists to help them support the action with scientific and technical plausibility. As a result, the cataclysmic premise, the special-effects wizardry, and the end-of-the-world plot are expected to satisfy both the critics and the moviegoers who want sci-fi drama that also sizzles with smarts. The scientists who consulted on the project say *Deep Impact* pays attention to everything from the comet's wispy coma, or fog-like shroud, to dialog as seemingly insignificant as NASA astronauts' radio chatter.

The story begins benignly enough with a serendipitous backyard discovery by 14-year-old amateur astronomer Leo Beiderman (Elijah Wood), who is assisted by astronomy professor Marcus Wolf. They find a new comet. The plot turns on the realization months later that Comet Wolf-Beiderman will come close to Earth. Still later scientists discover that the comet will . . . well . . . the movie's title offers a clue. Planetary scientists have feared that such a scenario, while extremely unlikely, will inevitably occur unless humans are somehow able to intervene.

Earth's impact craters are reminders of our vulnerability. Hundreds of comets and asteroids have been discovered, but each evokes concern and sometimes false alarms. For example, a few days after the 1995 discovery of Comet Hale-Bopp some astronomers thought its path intersected with Earth's orbit. More than a month later its true orbit was determined more precisely by using multiple observations of the comet's movement. Hale-Bopp came within Earth's cosmic ballpark — nine million miles away from the planet's orbit and about 165 million miles from the planet itself. Scientists agree that "periodic" comets, the class whose members fly by Earth on a regular basis — comets Halley, Swift-Tuttle, and Giacobini-Zinner — are most likely to hit Earth eventually. However, they would probably be able to give us about 100 years advance warning should a periodic comet veer into a collision trajectory.

Non-periodic comets — those that show up out of the blue and are never seen again — while much less likely to hit us, could, in theory, come directly at us and give us only a few days to prepare. If a non-periodic comet curved toward Earth on a looping, two-year collision course, as depicted in *Deep Impact*, scientists would need about a year to be certain that it would impact Earth. "It would take us about half the time before a newly discovered non-periodic comet on a collision course hits us to be able to say it definitely will hit," says Harvard University astronomer Brian Marsden.

DEEP IMPACT pays particular attention to the orbital mechanics of such a killer comet. Gerry Griffin, former director of NASA's Johnson Space Center and a *Deep Impact* technical consultant, says director Mimi Leder made more than 95 percent of the dozens of changes he suggested. "Scientists and engineers from NASA or the Jet Propulsion Lab are always the worst critics of these kind of films," said Griffin. "I hope they won't be too critical of the technical license that has to be taken to make this movie — you can't make it perfectly."

Leder, a two-time Emmy winner of *ER* who also directed *The Peacemaker*, enlisted the technical advice of geologist and planetary scientist Eugene Shoemaker prior to his death in 1997. Shoemaker's wife, astronomer Carolyn Shoemaker, also consulted on the film.

An ambitious television reporter (Tea Leoni), digs up a secret White House project with a feminine codename and concludes she has uncovered a Capitol Hill sex scandal. She hasn't, but President Tom Beck (Morgan Freeman) gives her the story of all stories. Soon, humankind realizes it must prepare for the end. Lives shift to warp speed. Griffin himself was cast as control center commander for Messiah, a spacecraft launched to blow up the comet with a nuclear bomb. In one subplot, the comet co-discoverer Beiderman and his classmate Sarah Hotchner (Leelee Sobieski) decide to marry in the little time they have left. "This epic drama is about people's reactions to the death sentence," says Leder. "What would you do if the world was going to end? That's why you can't just classify this movie as sci-fi."

CO-PRODUCERS Richard Zanuck and David Brown trace the inspiration for their movie to the 1951 sci-fi classic and Oscar-winner *When Words Collide*. Zanuck and Brown postponed their modern version, however, and went on to produce *Jaws*, *Jaws II*, *The Sugarland Express*, *The Sting*, and other films.

Their interest was rekindled when scientists discovered in the 1980s and 1990s that planets in the solar system and their moons had been struck many times in the distant past by huge asteroids and comets. Many scientists think a fiery impact 65 million years ago caused the extinction of the dinosaurs and many other forms of terrestrial life.

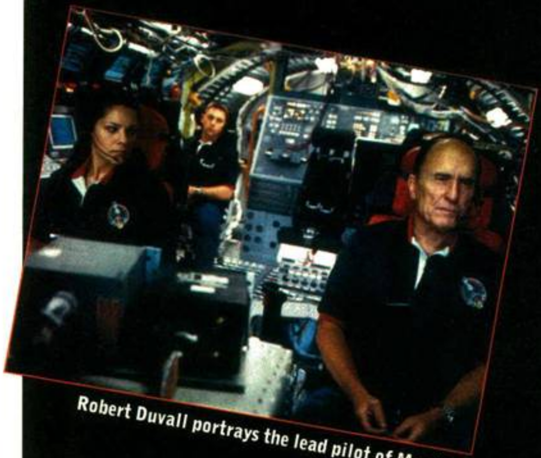
While much of the movie explores the choices people might make as they face a world that appears to be coming to an end, the film's special effects focus on the untested Messiah spacecraft and its astronauts. An aging astronaut played by Duvall comes out of retirement to add experience to a rookie team of astronauts on their mythic mission to the surface of the doomsday comet.

"There were occasions during the filming in a big Paramount studio . . . They had big fans blowing this broken up foam, and it was flying around like it was a big snow storm, and the astronauts were doing very dangerous things," Griffin says. "The little kid in me thought, 'These guys are on a comet,' and I kind of got lost in it." ■

All photos (except bottom right): Myles Aronowitz

Actor Jon Favreau is a space-walking astronaut.

Gaseous explosions complement the comet set.



Robert Duvall portrays the lead pilot of Messiah.

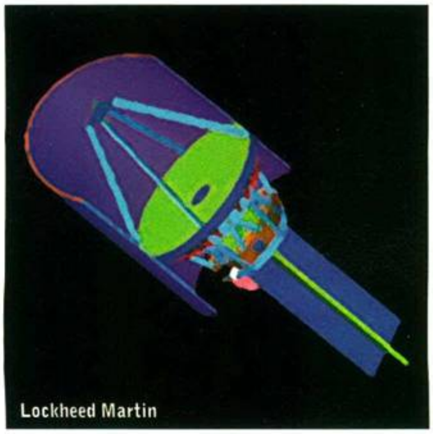
Special effects innovators create a cataclysm.

WHEN GALAXIES WERE YOUNG

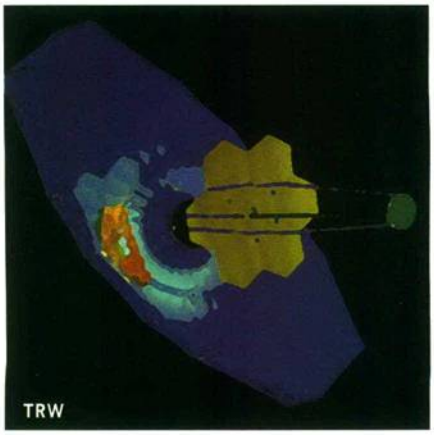
The Next Generation Space Telescope promises to decipher the origins of stars and galaxies. **by Anne L. Kinney**

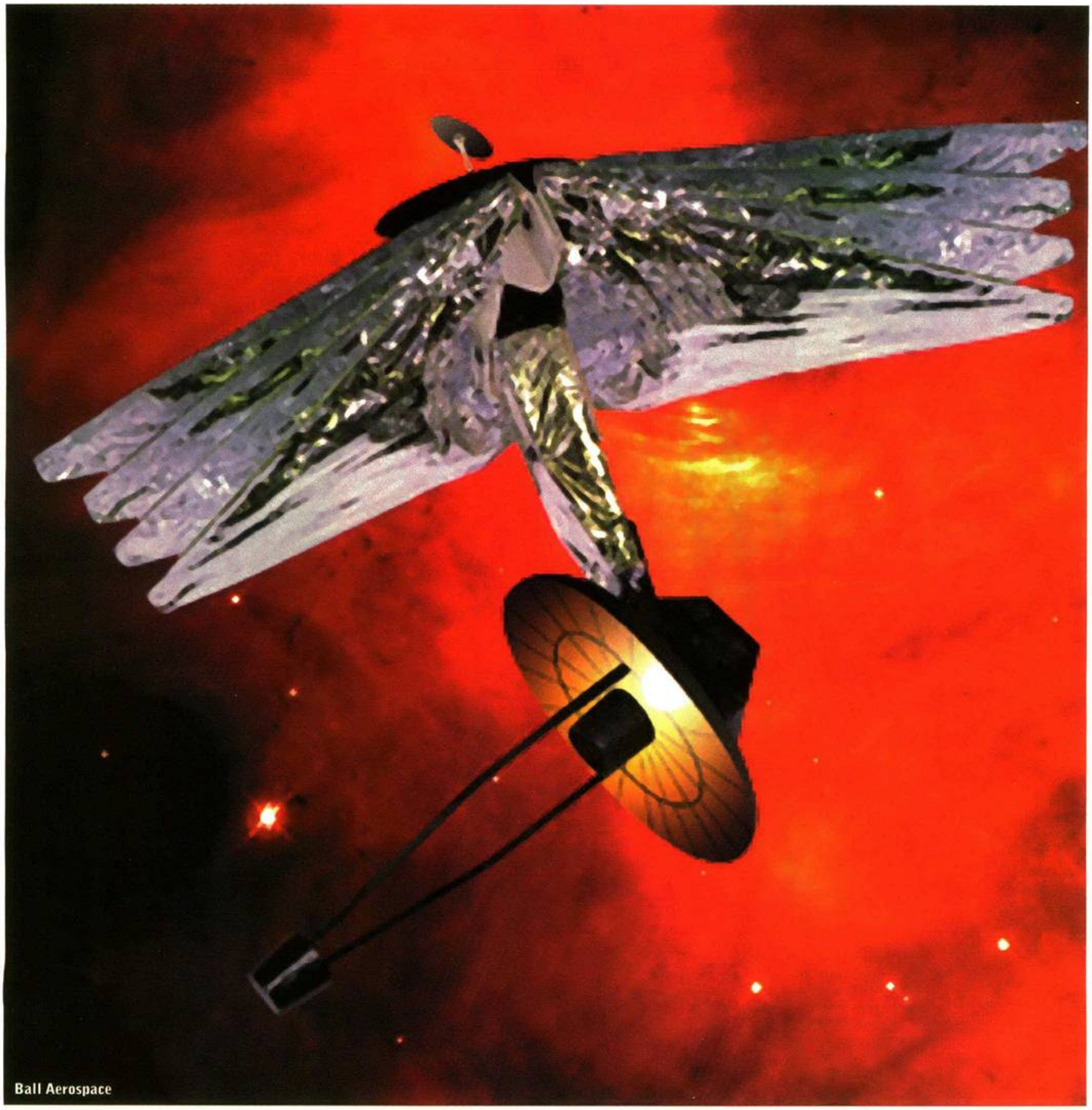
"FOR THE FIRST TIME IN HUMAN history, we have the opportunity to discover the origins of stars and galaxies." So says space scientist Jim Bilbro of NASA's Marshall Space Flight Center. Bilbro is one of dozens of scientists and engineers working on the most ambitious astronomical project of the age, the Next Generation Space Telescope (NGST). Designed to replace the Hubble Space Telescope, whose lifetime will end in a few years — it is expected to retire in 2005 — the new project will place an orbiting observatory into space that will push astronomical knowledge far beyond the domain of the current Hubble. With its 2.4-meter (94½-inch) mirror and array of instruments, Hubble has given astronomers the luxury of a finely tuned Earth-based telescope floating in space, outside the atmosphere that plays havoc with astronomical images. The plan for NGST, however, is to build a really large telescope especially designed for space, one that will feature a primary mirror at least 8 meters (320 inches) across. With the telescope, astronomers will take a substantial leap forward in their quest to understand some of astronomy's big questions. But the NGST breakthrough is still several years away.

NASA/GSFC


Lockheed Martin

For now, four independent teams have been working since early 1996 on possible designs for the NGST. Each of the teams, from Lockheed Martin, TRW, Ball Aerospace, and NASA's Goddard Space Flight Center, is vying for the chance to create the instrument, which will be launched with an expendable rocket rather than deployed by the space shuttle as was Hubble. The project timetable is approximate, with a possible choice of a contractor by 2000,


TRW



Ball Aerospace

construction underway by 2003, and a launch tentatively planned for May 2007. The launch by rocket brings challenge. "Designing the NGST is a little like designing a ship in a bottle," says project scientist John Mather of Goddard. "It has to fold up neatly, slip into a small cylinder, slide out again, and then become a completely functional, state of the art telescope all by itself."

Potential designs for the Next Generation Space Telescope include those of Lockheed Martin, Goddard Space Flight Center, TRW, and Ball Aerospace (left to right).

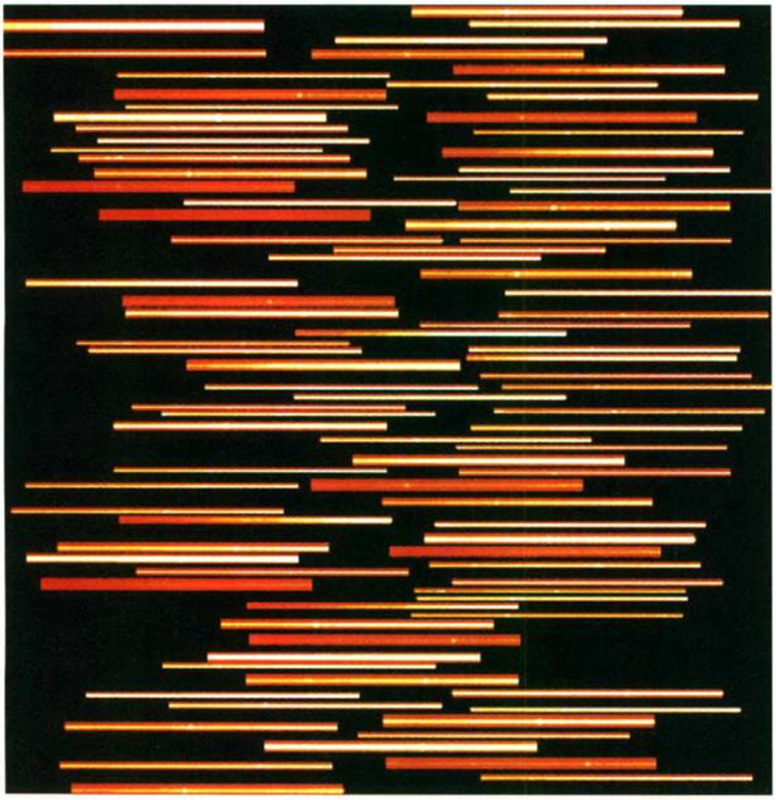
But if designed, constructed, and launched properly, the NGST will provide stunning payoffs. Its mirror will feature ten times the light gathering power of Hubble although the NGST will weigh only ⅕ of its predecessor. The telescope will be optimized for the near infrared, although it will produce data over a wide range of the spectrum. Unlike Hubble, it will not require servicing by astronauts. And, most unlike Hubble, it will be a deep space telescope orbiting Earth in a simple, distant orbit that will allow it to observe nearly round the clock for a lifetime of about ten years. The new scope will jumpstart astronomers' understanding of the beginning of the universe, the births of the first galaxies, the births of the first stars, and — perhaps most interestingly — the births of planets.

WHEN GALAXIES WERE YOUNG

"The NGST is our hope for the dark ages," says astronomer Len Cowie of the University of Hawaii, who wants to observe that brief time in the early universe when the first galaxies or quasars began to shine. Astronomers believe the NGST will reveal the early universe

90 percent of the way back to the beginning of time. If they get their wish, they will be able to watch the first stars and the first supernovae.

They almost certainly will get a ringside seat at the formation of galaxies, a milestone advance. About five years ago, as the first images came in from Hubble showing distant galaxies, a revolution began. As astronomers peered at galaxies five, nine, and even 12 billion light-years away, they began to see the early lives of galaxies in a new way.



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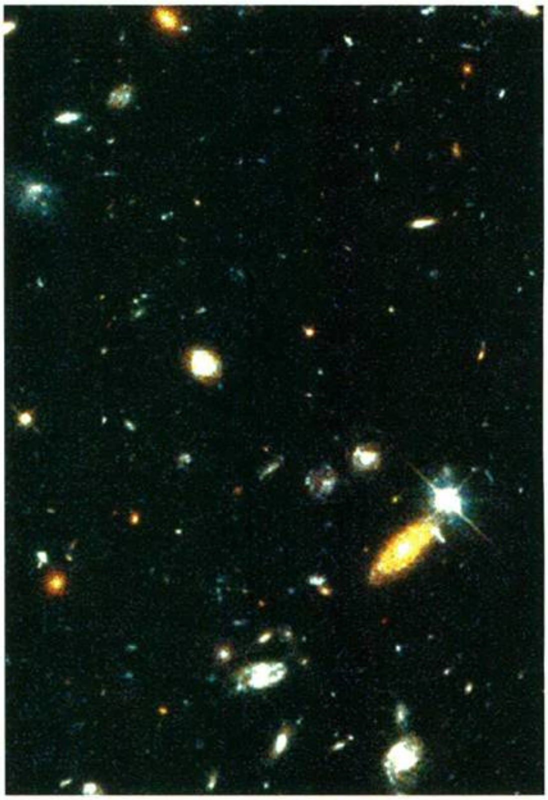


A simulated spectrum of galaxies from the Hubble Deep Field suggests the power the NGST will bring to galaxy research by recording hundreds of spectra at once.

"We have now seen galaxy formation," says Simon White of the Max-Planck-Institut für Astrophysik, "and it is not an event but a process." When astronomers see galaxies nearby, they are looking at the result of recent star formation. Galaxies are now believed to form stars in short-lived waves. So the structures of many of the galaxies we see around us in the universe, the spirals and barred spirals, may be the result of relatively recent activity within these galaxies. "We got morphologies of galaxies with Hubble," says Richard Ellis, an astronomer at the Institute for Astronomy in Cambridge, England. "But we now realize that morphology may be transient."

Because of this shift in awareness, astronomers now use a new word to describe how galaxies come together — they don't just form but are assembled. The assembly takes place later on from components that form early in the universe. Astronomers are now engaged in a lively debate that may be solved by the NGST about what the original pieces of galaxies were and how they took shape. The debate centers on whether big clumps form first and smaller pieces later, or vice versa. In both scenarios astronomers seem to agree that stars formed very early on.

But did stars then clump into star clusters, star clusters into galaxies, and galaxies into clusters of galaxies? Or did galaxies form when huge gas clouds collapsed and created clusters of galaxies, and then galaxies? To find out, astronomers need a telescope like the NGST that will transport us back into the dark ages.

The NGST will also have the sheer light-gathering power and resolution to get at the most complex questions of cosmology. The current puzzle centers on how the universe we now live in — some 15 billion years old — is clumpy, whereas the very ancient universe as observed with the Cosmic Background Explorer satellite appears to be smooth, some 300,000 years after the Big Bang. How did the universe go from gentle smoothness to chaotic clumpiness?

Astronomers' best guess is that it wasn't actually so smooth way back when. Fluctuations in the density of the universe must have been around in the very early universe in order to produce the waves of galaxies that formed, but perhaps these fluctuations were suppressed as the universe heated up.

The early warming of the universe, known as the period of reionization, witnessed electrons separating from protons and may have been caused by radiation from the first stars as they turned on or by light from the earliest quasars. It may be that low-mass objects collapsed and began to shine, creating bubbles of glowing hydrogen surrounding them. Later, heavier objects formed, and as time passed, more and more regions of ionized gas evolved so that they eventually overlapped and all of the universe sat aglow, bathed in ionized hydrogen that raised the temperature of the universe.

GOOD MORNING STARSHINE

Researchers who get the first cracks at using the NGST will undoubtedly attempt to look back toward these earliest pockets of stars and bubbles of gas in the ancient universe. The evidence for such early stars in fact comes from observations of quasars. Quasars are extremely bright objects that serve as beacons from the distant past. By looking at quasars and observing the wavelengths of light that are absorbed from their images — by gaseous objects lying between us and them — astronomers can surmise the distances of intervening objects and the various abundances of the elements that make up the gas.

What astronomers see is that the elements heavier than hydrogen and helium — elements created after the Big Bang — are not only present in the distant past but are ubiquitous. Because these so-called heavy elements are created in the centers of stars and spread throughout the universe by supernova explosions, stars must have been around in the early universe, before galaxies are known to have formed.

Where are these ancient stars now? The massive ones born in the early days of the cosmos lived brief lives that ended as supernova explosions, wherein they spewed nuclear byproducts such as carbon, nitrogen, oxygen, and iron into the gaseous medium that surrounded them. This sequence of events was especially fortunate for us, as we are made out of these materials. Astronomers have not yet seen these first supernovae, something that would confirm our notions of the whole early star formation history of the universe, but they expect the NGST will offer the ability to image the ancient echoes from early star deaths. Really low mass stars that formed in the first days of the universe will have survived and be present in today's universe.

The NGST may provide astronomers with a continuous set of observations over time that will allow a more thorough understanding of how and when ordinary stars formed and how they have evolved over the history of the universe. This offers astronomers the possibility of leading to a significant breakthrough.

SEEING THE WORLD IN INFRARED

Most of the light we see in our daily lives is reflected light. We also see light that is emitted from objects directly, however, such as that from the sun, an incandescent light bulb, or a candle. If we turn off a room light, the room appears dark, but that's only because human eyes are designed to see visible light and not other wavelengths like infrared, the kind of radiation emitted by room-temperature objects. Human bodies emit infrared light at a slightly higher temperature than room-temperature objects; humans emit hundreds of watts of infrared energy at a wavelength of about 10 microns.

Imagine a telescope like the Next Generation Space Telescope designed to detect infrared light. If the telescope is at room temperature or if it is orbiting Earth and being warmed by the sun, it will emit infrared radiation. It would detect mostly infrared light coming from itself. Because of this, infrared telescopes must be cooled so they don't emit infrared light that would contaminate their own observations. The NGST probably will be passively cooled and shaded from sunlight by a massive sunshield that will be deployed in orbit.

THE FOSSIL BONES OF NEARBY GALAXIES

"The fossil record of stars gives us our ultimate check on whether our grand interpretations of the distant universe are correct," says astronomer Mike Rich of Columbia University. "More importantly," Rich continues, "the insights the NGST obtains will show us the processes at work as our galaxy and others came together. This is something that looking at the distant universe directly can't tell us." Such insights may come because the history of a galaxy is recorded in the lives of its stars. The oldest stars in the Milky Way Galaxy, for example, may date as far back as 15 billion years. The ages of the oldest stars measured by Hubble, in the Large Magellanic Cloud and in one of the Milky Way's globular clusters, turn out to be about the same. It's hard to imagine this merely as a coincidence.

Astronomers using the NGST should be able to measure ages of galaxies within the Local Group, our regional cloud of spirals and dwarfs. From this, astronomers hope to reconstruct the story of how a large number of galaxies formed and understand how their populations of stars came to be. One thing they are wondering about: whether the first waves of stars formed at various times in the Local Group galaxies, or if they formed at about the same time. The answer may lie among the smallest stars and brown dwarfs, where the longest record of the universe lies buried.

THE TELLTALE BROWN DWARFS

"Why study brown dwarfs?" asked Keith Noll of the Space Telescope Science Institute at a recent science meeting. "Are they cool stars, or just infrared vermin?" Recently discovered at Palomar Mountain Observatory and confirmed by Hubble, brown dwarfs are often called failed stars. They are cooler and smaller than the coolest and smallest stars. They are so cool that they are invisible to our eyes. The easiest way to detect these objects is to spot their infrared emission.

Brown dwarfs are important because they may be so numerous that they constitute one of the largest reservoirs of matter in the universe. Astronomers suspect their great numbers through surveys of nearby stars. In the neighborhood of the sun, there are few massive stars. Astronomers have found many more intermediate sized stars and even more small stars. If this trend carries, brown dwarfs should exist in large numbers. They may be so plentiful that they account for a good part of the so-called "missing mass" in the universe, the matter astronomers know exists but have yet to find.

The problem is a difficult one, though: Because brown dwarfs do not glow like ordinary stars undergoing nuclear fusion, they are extremely faint and a telescope like the NGST will be required to begin to find more brown dwarfs in the neighborhood of the sun. For the NGST, even, detecting them will be a challenge.

HOME SWEET HOME

The sun's neighborhood will indeed undergo scrutiny from the NGST. The telescope will be used for example to study the Kuiper belt, the skeleton of the protoplanetary disk from which our solar system formed. As the solar system evolved, leftover material in the region between Jupiter and Neptune was cast out of the plane of the solar system by the gravitational pull of the outer planets. It was planted on the very periphery of the sun's family in the shell of asteroids and comets known as the Oort cloud. But outside of Neptune's orbit, the leftovers were mostly undisturbed. They remained in orbit about the sun in the plane of the solar system, forming the Kuiper belt. Such a region of asteroids and debris was hypothesized by astronomers as early as 1949, but only in the last several years have they begun to discover asteroids clearly belonging to the Kuiper belt.

The largest members of the Kuiper belt, with sizes about 60 miles across, were discovered by astronomers David Jewett and Jane Luu of the University of Hawaii starting in 1993. Smaller Kuiper belt objects measuring only three or six miles across were uncovered by Anita Cochran of the University of Texas and others using Hubble beginning in 1995, observing at the threshold of what Hubble could detect.

Astronomers' understanding of the Kuiper belt is pretty basic at this point: The NGST will let us assemble a more cohesive picture of the orbits of the Kuiper belt objects and provide a better survey of their sizes. From this, astronomers will be able to understand the history of ancient collisions between objects in the vicinity of the Kuiper belt.

BUILDING THE NGST

Because the universe is expanding, the farther back astronomers look in time, the more the light they see gets shifted to longer wavelengths. There's so much expanding space between billions of years ago and now that light emitted in the ultraviolet long ago gets redshifted in our telescopes all the way into the infrared.

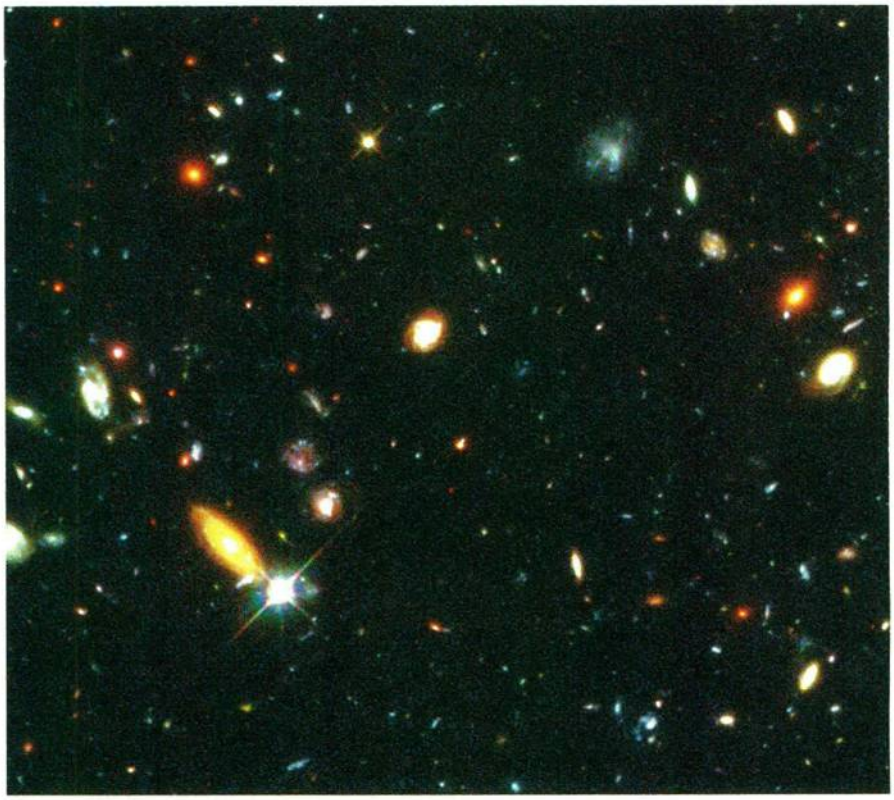
Additionally, the oldest stars, the smallest stars, planets, and Kuiper belt objects are all citizens of the universe that emit most of their energy in the infrared. Clearly, the infrared part of the spectrum is crucial to any space telescope of the next generation.

Technology in engineering and manufacturing has progressed to the point where astronomers and contractors are confidant that the NGST can be created efficiently at reasonable cost. Indeed, the whole concept of the NGST was mandated by NASA Administrator Daniel Goldin to be possible only if the cost were $500 million or less. "It's now possible to build the NGST because of immense progress on the ground," says Mather. "Segmented telescopes with high-speed adjustments to track the atmospheric fluctuations are working now, and in many ways, the NGST problem is much simpler — there's still no air in space."

The movement is toward technologies that allow astronomers to launch lightweight components into deep space with expendable rockets, to launch mirror segments and assemble them in space, to adjust the mirror segments in a very large telescope in real time. These advances will allow astronomers to increase the sensitivity of the instrument dramatically while still holding the reins on the price tag.

Hubble weighed in at 11,000 kg, but the NGST will weigh a mere 2,800 kg despite the fact that it will be 10 times larger. Innovative support structures built into the telescope and an ultralight mirror will make most of the difference. The telescope will be launched into orbit with an expendable rocket, saving both on the direct costs of operating the space shuttle and on the costs of verifying the safety of the crew from telescope components.

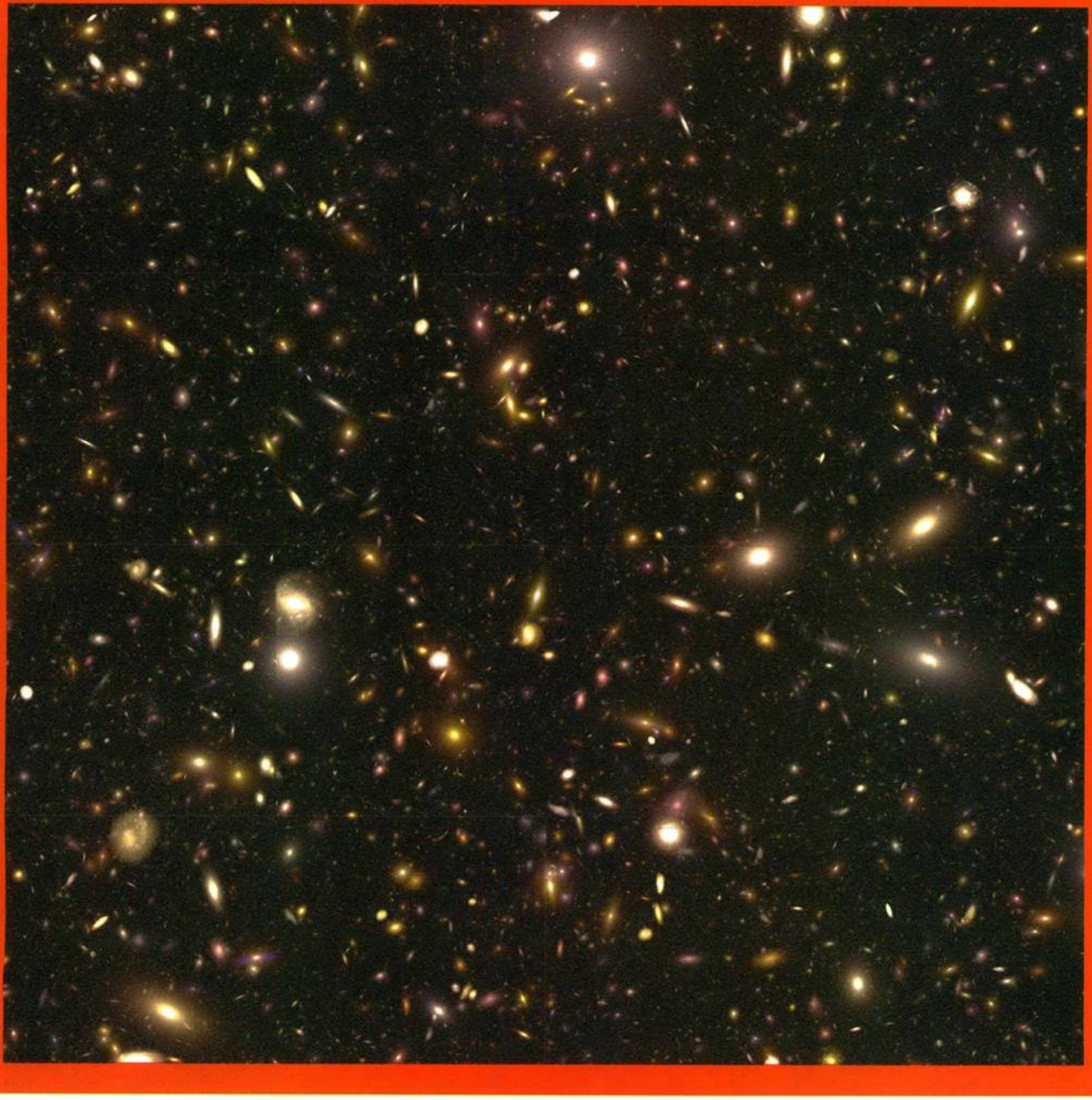
The scope's optics will be designed to allow for on-orbit adjustments, saving on the elaborate and, as witnessed with Hubble, risky grinding of mirrors to perfection on the ground. "The NGST will be the first optical telescope in space to take full advantage of the space environment," says Mather. "No gravity, the stable thermal environment of deep space, and no need for a protective telescope tube." While Hubble was basically a ground-based telescope transported into space, the NGST will be designed for space from the get-go.


STScI

The Hubble Deep Field, a cornerstone of current research on galaxy formation.

The study teams of Lockheed Martin, TRW, Ball Aerospace, and Goddard have somewhat different visions of the NGST. The Goddard team foresees a telescope with nine mirrors and an inflatable, octagonal sun shield that unfolds during its trip from Earth to its spot in orbit one million miles away. The TRW team conceives of a six-segment mirror with a sun screen made of silvered teflon that varies in shape and

NGST DEEP FIELD SIMULATION



Myungshin Im/STScI

A simulation of a deep exposure with the NGST reveals thousands of galaxies beyond the reach of the Hubble Space Telescope.

reflectivity with needs. The Lockheed Martin team proposes a 6-meter monolithic mirror, a mere two millimeters thick, that would be placed in orbit around the sun. Ball Aerospace proposes a 6-meter to 8-meter design.

Whichever design is chosen, the NGST will attack some of the big questions in astronomy. "What is required for the universe to be suitable for life?" asks Alan Dressler of the Carnegie Institution. "What abundance of heavy elements does it take to form Earths, and when did galaxies first cross this threshold? Are galaxies even necessary for life?" Dressler's questions and others should be answered by the NGST.

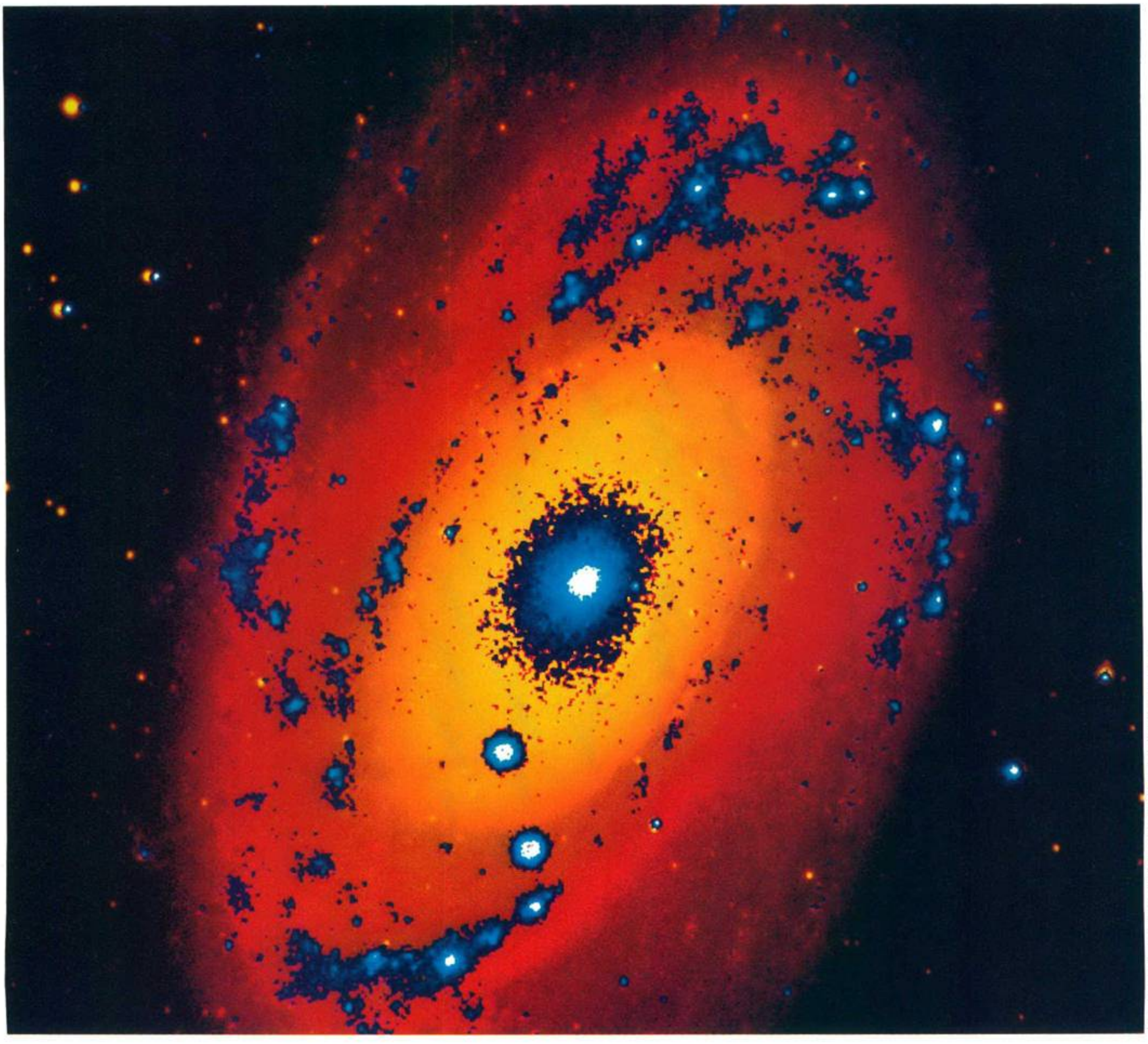
"The Hubble Space Telescope has shown us the incredible benefits of doing astronomy in space," says Mather. "Even though Hubble is only 1⁄16 the size of the Keck telescope, its pictures are far sharper and deeper." Now if we can build the NGST to be nearly as large as the Keck, Mather contends, astronomers can do even better. "Because we can cool the NGST to low temperatures, it will also exceed by far the capabilities of all of the smaller infrared telescopes we have worked so hard to build." Mather is clearly excited. "The Next Generation Space Telescope will start a revolution in infrared astronomy," he says. Let the revolution begin. ■

Anne L. Kinney is an astronomer at the Space Telescope Science Institute in Baltimore. She is also a member of Astronomy*'s editorial advisory board.*

COSMIC JEKYLL HYDE

A galaxy in ultraviolet light takes on a whole new look, a cosmic case of Dr. Jekyll turning into Mr. Hyde.

by Marcia Bartusiak

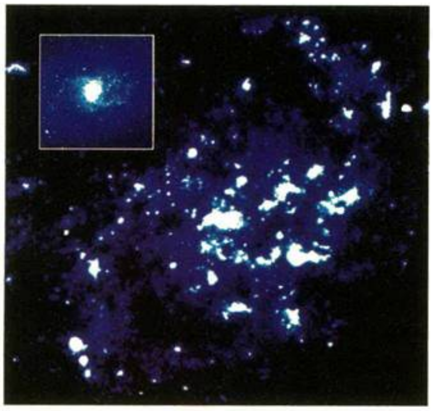


All images: Theodore P. Stecher (NASA/GSFC) and the UIT Science Team

Of the many branches of astronomy, there are two that rarely mingled in the past. The entire universe once stood between them.

In one of those branches reside the astronomers who largely study the nearby universe, specifically our cosmic neighborhood in ultraviolet light. Ultraviolet light consists of invisible waves given off by particularly hot objects. It occupies a special slice of the electromagnetic spectrum: more energetic than the blue and violet light visible to our eyes, but less powerful than x rays and gamma rays. Through this window, observers can spy hot interstellar gases, active galactic centers, and bright, blue-white, newborn stars.

Astronomers in the other branch patiently probe the distant universe, attempting to collect the trickle of visible and infrared rays emanating from the farthest reaches of the cosmos. Once a thankless task, this enterprise has recently blossomed due to advanced detectors and new instruments, such as the Hubble Space Telescope and the giant Keck telescopes on Hawaii's Mauna Kea. As a result, astronomers can now view galaxies situated several billion light-years away (and, given the time it takes light to travel, billions of years into the past). They are at last unveiling the infant universe.



The ultraviolet view of spiral galaxy M33 shows active star formation. A visible light image is shown (inset) for comparison.

But how should astronomers interpret those far-off signals? Although observers of the distant universe are gathering visible light waves with their optical telescopes, those rays left the young galaxies as ultraviolet light. After journeying across the vast oceans of space over billions of years, these very short waves get stretched — highly "redshifted" — with the universe's expansion. By the time they reach Earth, ultraviolet waves are lengthened to visible and infrared wavelengths. Yet, distant-galaxy hunters are still observing an ultraviolet universe, only one far younger and more remote. To fully understand what they are seeing, they need to compare notes with the ultraviolet experts in the other branch.

In this montage of spiral galaxy M81, the orange and yellow correspond to visible light, while the blue and white knots mark intense ultraviolet emission — where the hot, newborn stars have formed.

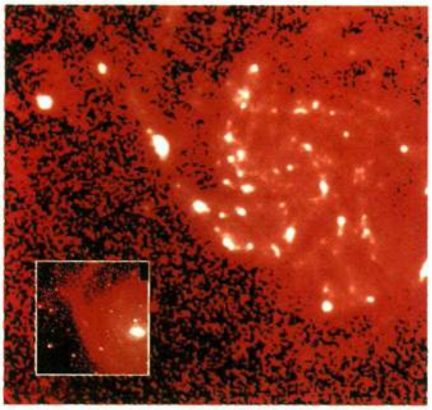
With that in mind, the two diverse groups finally met last spring for a three-day conference at the University of Maryland. "It was an idea whose time had come," said conference organizer William Waller, an ultraviolet astronomer at NASA's Goddard Space Flight Center, at the opening session. Conferees received violet-ink pens to mark the occasion (as well as their notebooks). Here was the opportunity for cross-talk on the "ultraviolet universe at low and high redshift," the title of the meeting.

THE ULTRAVIOLET UNIVERSE IS LESS KNOWN THAN THE RADIO, INFRARED, OR X-RAY sky. "It's wavelength chauvinism," declared Jay Gallagher of the University of Wisconsin. "But to understand the far universe, we have to understand the ultraviolet." Ultraviolet images are few, however, partially because most ultraviolet light is filtered out by atmospheric oxygen and ozone before it reaches the ground (which is fortunate because it causes sunburns and skin cancer), a fact which makes spaceborne detectors necessary.

Although the International Ultraviolet Explorer was one of the longest running space telescopes (launched in 1978 and expected to last three years, it operated until 1996), its data were spectroscopic. Astronomy's first successful ultraviolet image, taken by Apollo 16 astronauts in 1972, was a portrait of the Large Magellanic Cloud, the Milky Way's largest satellite galaxy. Since then, ultraviolet images have come from three chief sources: high-altitude balloons, the Hubble Space Telescope, and the Ultraviolet Imaging Telescope, part of the Astro Observatory flown aboard the space shuttle in 1990 and 1995.

These instruments reveal regions of active star formation — populations of stars less than a billion years old and thousands of degrees hotter than ordinary stars. Such hot sources can be 100 times fainter in visible light (where ordinary stars stand out), because they emit most of their light in the ultraviolet. Consequently, a galaxy in the ultraviolet takes on a whole new look, a cosmic case of Dr. Jekyll turning into Mr. Hyde.

Take the Large Magellanic Cloud, for example. Through optical telescopes, it looks like a broad swath of diffuse light. In the ultraviolet, however, "It's a mess: clumps of glowing sources," noted Robert O'Connell of the University of Virginia, as he displayed the image to conferees. His next picture depicted the Pinwheel Galaxy (M33) in Triangulum, whose spiral arms look so smooth and symmetrical in visible light. With ultraviolet eyes, however, it appears fragmented and disorganized. M81, a beautiful spiral in Ursa Major, was another example. Its large central bulge, quite prominent in visible-light images, turns into a small droplet in the ultraviolet, surrounded by a ringlike necklace of spiral arms.



Spiral galaxy M101 looks familiar in visible light (inset), but it takes on a whole new appearance when viewed in ultraviolet light.

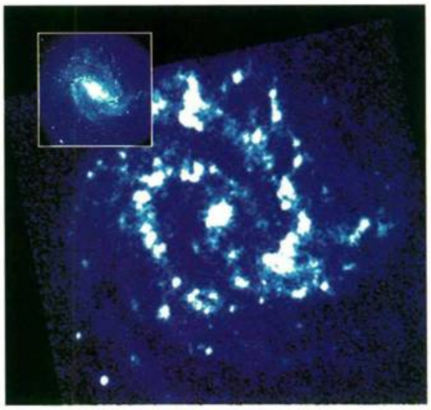
Older populations of more ordinary stars, too cool to emit much ultraviolet light, become invisible in the ultraviolet. Similarly, the bars in barred spiral galaxies can disappear altogether when viewed in ultraviolet light. O'Connell pointed out that the Hubble Deep Field, a recent probe by the Space Telescope of the distant universe out to some 12 billion light-years, uncovered few barred spirals. "Maybe that's a reflection of this effect," he remarked.

INDEED, NOTING SUCH TRANSFORMATIONS BETWEEN THE ULTRAVIOLET- AND VISIBLE-light universe is crucial for understanding the far universe. Astronomers must know what a local galaxy looks like in the ultraviolet in order to differentiate a true evolutionary effect in a distant galaxy — an event uniquely linked to the galaxy's birth — from normal, everyday ultraviolet occurrences.

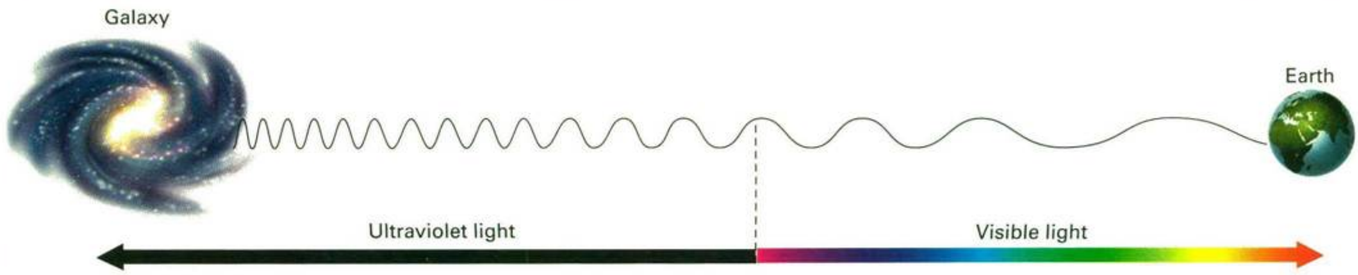
"There is a systematic bias," cautioned Tony Tyson of Lucent Technologies on day two of the conference. "Things are dimming as we proceed outward. Normal things tend to look like points of light." A particularly bright knot of star formation awash in ultraviolet light, he warned, might be the only thing seen at a distance and thus be mistaken for an unusual galaxy.

Others are not so sure. Roberto Abraham of the Royal Greenwich Observatory in England has been comparing galaxies at both high and low redshift and claimed that distant galaxies are of another class altogether. Surveys of the distant universe are indeed revealing a rather strange cosmos. The Canada-France redshift survey, an extensive examination of galaxies halfway back to the Big Bang, reveals many blue irregular galaxies. The Hubble Deep Field displays numerous ragged galaxies and compact nuclei surrounded by fuzzy nebulosities. Are these merging galaxies? Are they fragments just now coalescing into full-blown galaxies? Or are they normal galaxies that only appear peculiar because they are being viewed in ultraviolet light redshifted into visible light?

To solve the puzzle, Abraham took a sample of typical local galaxies and modeled how these galaxies would appear if suddenly redshifted more than halfway across the universe. Generally, central bars disappear and spiral arms turn into rings, just as observed in images from the Ultraviolet Imaging Telescope. But after comparing these results with the Hubble Deep Field, he concluded that the early universe still has far more irregular, peculiar, and merging galaxies than our local galactic neighborhood. When looking at the Deep Field, he said, astronomers are seeing proto-galaxies that are "experiencing their first burst of star formation." Some spectral studies back him up; they indicate that the stars in these far galaxies look rather young, no more than two billion years old.



Although M83's spiral arms are prominent in visible light (inset), they stand out even more in ultraviolet light.



Short-wavelength ultraviolet waves coming from the distant universe are stretched into longer-wavelength visible light waves by the universe's expansion. So when astronomers look to the distant universe in visible light, they are actually studying light that originated in the ultraviolet.

Astronomy: Elisabeth Rowan

Chris Martin of Caltech reached a similar conclusion but with a different approach. Analyzing data from a balloon-borne detector, he examined some 95 galaxies at varying distances. He claims that there are more galaxies shining in ultraviolet light than in visible as the universe is probed farther and farther outward. This implies a dramatic evolution in star formation through time. The Milky Way currently makes one or two stars a year. But when the universe was several billion years younger, says Martin, galaxies were producing 50 to 100 solar masses worth of stars each year. The early universe was an epoch of starbursting, which means galaxies starbursting today might serve as a model of that former era.

But Claus Leitherer of the Space Telescope Science Institute wondered if that's truly the case. After examining spectral information from several telescopes, he concluded that early galaxies weren't bursting so much as they were simmering — undergoing vigorous but not explosive star formation. "Nearby starbursters may not be the best template for interpreting high redshift spectra," Leitherer advised his fellow astronomers.

SUCH DIVISION OF OPINION WAS SEEN THROUGHOUT THE CONFERENCE, WHICH IS NOT unexpected when information is so new. Astronomers are only getting their first glimpse of the far universe and many obstacles stand in their way. Stars, for instance, form in regions of dust, which absorb and scatter ultraviolet light. Part of the signal from the far universe is thus lost, making interpretation more difficult.

The feistiest debate at the meeting concerned what the ultraviolet signals from the early universe are telling us about galaxy evolution. Some contended that the distant objects are "sub-galactic clumps" in the act of merging into the galaxies of today. Galaxies, they said, did not condense out of huge gas clouds fully formed from the start. Rather, they assembled from small disks of gas, each about 3,000 light-years wide, joining to form a spherical bulge. Later, some of these bulges might enwreathe themselves in gas and turn into spiral galaxies. Some of these spirals, in turn, could collide and merge to form giant elliptical galaxies.

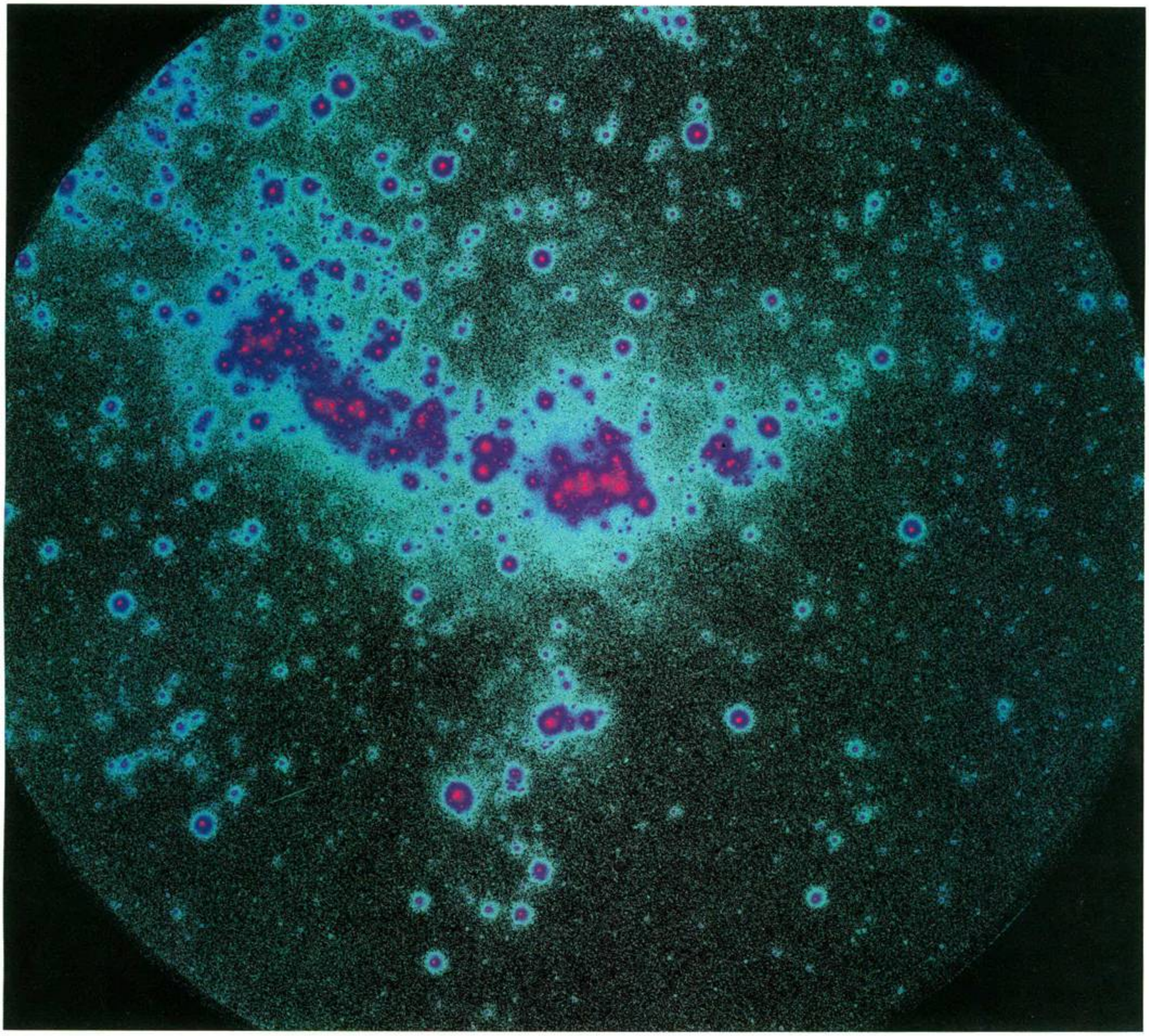
But others cautioned that the ultraviolet information from the far universe could be misleading. Instead of small galactic building blocks, the distant objects might be pockets of intense star formation embedded within larger galaxies. Indeed, some claim they are seeing full-size galaxies already in place and at a time when the universe was a mere babe, just 15 percent of its current age. This implies that the biggest galaxies formed fairly quickly and then coasted into the modern era largely intact while smaller galaxies coalesced later.

More ultraviolet data would help settle these conflicts, but the last ultraviolet all-sky survey was conducted more than two decades ago. Noah Brosch of Wise Observatory in Israel noted that the future "looks bleak" and blamed it on a lack of "sexy discoveries." With few instruments on hand, ultraviolet astronomy didn't find interesting objects such as pulsars, black holes, and quasars, the type of finds that propelled the fields of radio and x-ray astronomy. "We're a hundred years behind optical astronomy," lamented Brosch.

Ultraviolet astronomers will have the Far Ultraviolet Spectroscopic Explorer, scheduled to launch at the end of 1998. And there's talk of dedicating the Hubble Space Telescope to ultraviolet studies once the Next Generation Space Telescope goes up. "For the next 10 to 15 years, NASA's 'big ticket' missions are all in the infrared rather than the optical and ultraviolet," noted O'Connell. "But the optical-ultraviolet is the most information-rich part of the electromagnetic spectrum. Our concern is that, even though missions like the Next Generation Space Telescope will observe the ultraviolet light of very distant objects that has been redshifted into the visible, we won't have the wherewithal to understand them very well because we can't do our ultraviolet 'homework' on nearby systems." To catch up to their colleagues in the neighboring bands of the electromagnetic spectrum, ultraviolet astronomers may just have to be patient. ◼

Award-winning science journalist Marcia Bartusiak is a member of Astronomy*'s editorial advisory board.*

A small section of the Large Magellanic Cloud looks like a glowing mass of clumps in ultraviolet light. All of the ultraviolet images in this article were taken by the Ultraviolet Imaging Telescope, which flew aboard the space shuttle in 1990 and 1995.



Crack in the Clockwork

The solar system may have lost several planets, and Mercury or Mars might be the next to go.

by Adam Frank

FOR MORE THAN TWO millennia humans have looked to the planets as the embodiment of reason, order, and harmony. The planets' steady paths have echoed the archetype of modern science's vision of a universe — a clockwork universe, a universe in which planets orbit their sun in a stately, predictable manner. Now at the end of the millennia, the clock has been shattered.

Using the most powerful computers available and an even more powerful idea known as chaos theory, astronomers have discovered that planetary orbits are not celestial metronomes. They do not count perfect, stable beats across centuries. Instead, a new vision of our solar system and possibly those beyond is emerging where planets may ride forever on the fragile edge of disaster. The solar system is not a clock, but instead a hornets' nest of chaos, and not all planets are guaranteed permanent residency.

The Birth of a New Science

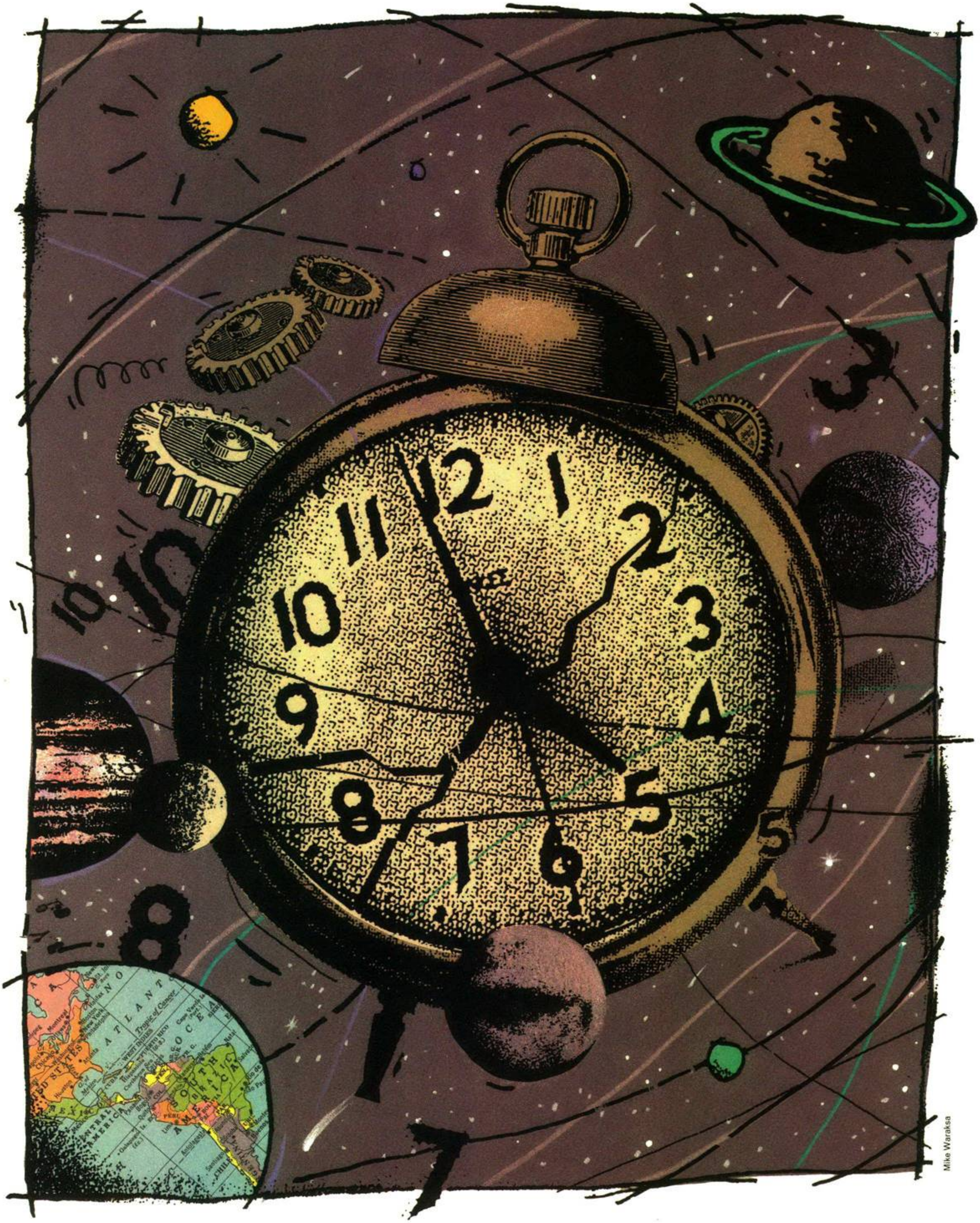
Chaos theory is not only reshaping our view of the solar system, it is actually a constellation of ideas powerful enough to affect almost all scientific disciplines. Chaos theory focuses on the broad class of phenomena known as "dynamical systems," collections of "things" that move and interact. Examples of dynamical systems include the scatter of billiard balls after a break, the weather, and the silent dance of planets in orbit around a star. The fundamental question chaos theory asks of these systems concerns stability. In some sense stability means repeatability. Will the system repeat its motion even if initial conditions change slightly? The question can be rephrased to "How sensitive is the system to initial conditions?"

Take a concrete example from the pool table: If my bank shot worked once, will it work again if everything is exactly the same but a fly lands on the table? Could a butterfly flapping its wings over Beijing, China, determine whether or not it rains in New York City one month later? A more extreme and germane version of this question would be: Could a space shuttle launch provide enough kick to toss Earth out of its orbit and hurtle it into the frigid depths of interstellar space billions of years later?

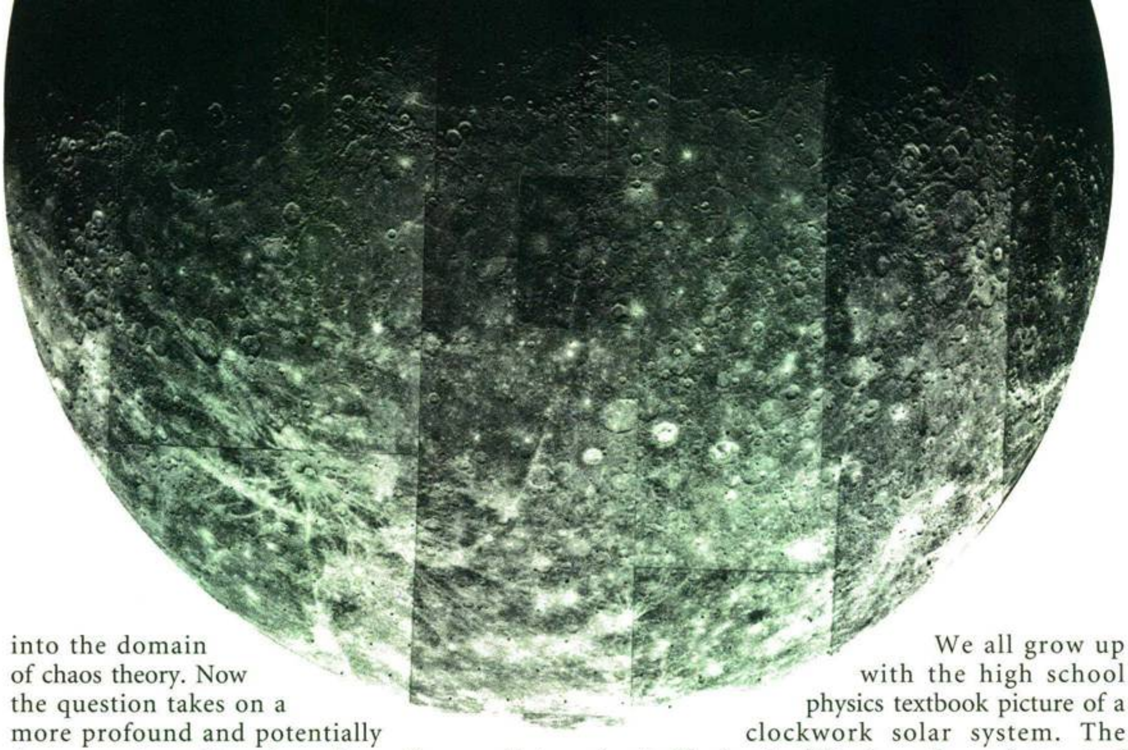
Ever since Isaac Newton we have been taught to think that small events should have small effects. That tiny fly should have little consequence for my bank shot. A butterfly should not affect the weather in New York. A single rocket launch shouldn't change the course of an entire world. What has made chaos theory so startling to scientists and so newsworthy to the public is its final and forceful refutation of this 300-year-old prejudice. While the examples chosen above are extreme, chaos theory has revealed something fundamentally new. The world, we have discovered, is complex in the deepest sense of the word. Chaos theory has shown us that even the minuscule weight of a fly can tip the scales and decide the fate of worlds.

Death of the Solar System?

When it comes to planets, what is so special about the number nine? Why does our solar system have nine planets and not 12 or eight or six? This is more than a simple question of origins. It is also a question of stability, and that brings it



Mike Waraksa



A goner? Mercury has a small but finite chance of getting thrown out of the solar system after a close encounter with Venus. NASA/JPL

into the domain of chaos theory. Now the question takes on a more profound and potentially dangerous tone. How do we know for sure that Earth's or any other planet's orbit is eternally stable? As George Lake of the University of Washington puts it, "Perhaps there is nothing special at all about the number nine. It may just be a matter of *when* you look."

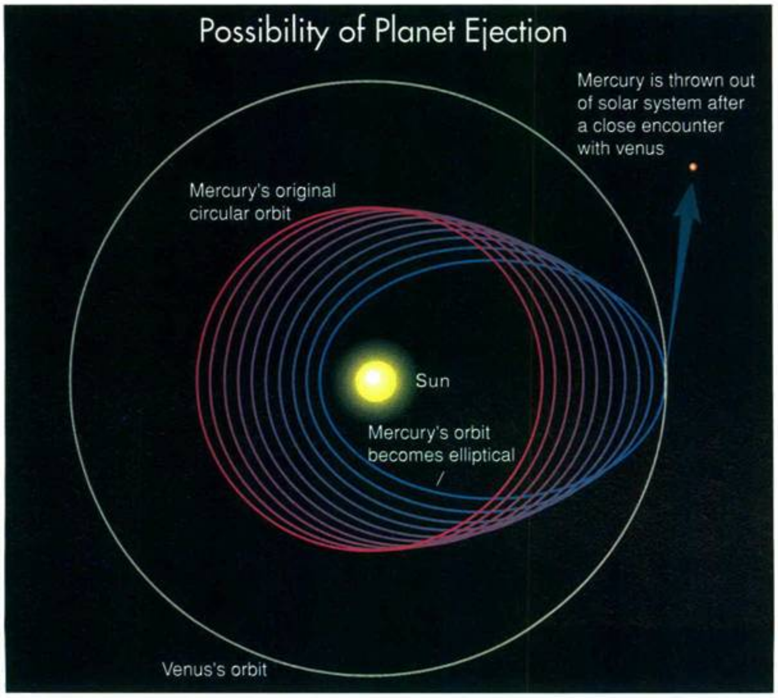
According to Lake, who also directs NASA's high performance computing program, astronomers have long believed that the solar system was, on the whole, unchanging. "It was our model of stability, but chaos is changing that," he says. "Now we understand that planets may not get permanent membership in their solar systems. Is it possible that a billion years ago there were 12 planets and, perhaps, a billion years from now there may only be six?"

We all grow up with the high school physics textbook picture of a clockwork solar system. The planets, like beads, slide along the perfect arcs of their nested concentric orbits. In reality, each of these orbits is continually deformed by the gravitational pull of all the other planets. Jupiter, of course, weighs in with the largest gravitational force in the solar system not counting the sun, but even the smaller planets can affect the shape of their neighbors' orbits.

Astronomers who study the stability of the solar system must first understand how this multitude of forces operates. In principle and practice, they have to know the orbit for each planet for all time — a tall order indeed. As Newton wrote three centuries ago, "The orbit of any one planet depends on the combined motion of all the planets, not to mention the actions of all these on each other. To consider simultaneously all these causes of motion and to define these motions by exact laws allowing of convenient calculation exceeds, unless I am mistaken, the forces of the entire human intellect."

The addition of chaos theory has made the problem even more complicated. Instead of one set of orbits, astronomers are forced to simultaneously consider the set of all possible orbits. Imagine a child's schoolbook image of the solar system with its nesting of brightly colored orbits centered on the sun. Chaos theory changes this picture in a dramatic way. Now each orbit, which we think of as a stable path around the sun, is replaced by a tightly woven bundle of orbits, an infinitely tangled web of paths. Some of these are stable and loop back on themselves forever. Others are unstable; they loop around the sun for a finite time before their orbits become more and more elliptical. Eventually they are thrown out of the solar system after a close encounter with a neighboring planet. The sensitivity that is the hallmark of chaos lies in the tangled web. With all those stable and unstable orbits woven together, might not the launch of the space shuttle push

Due to the gravitational influence of the other planets, a planet's orbit sometimes becomes more and more eccentric over time. Finally, its orbit can become so eccentric that it crosses the orbit of another planet. When the two planets pass close to each other, one of them (usually the less massive member) gets tossed out of the solar system.


Possibility of Planet Ejection
Mercury is thrown out of solar system after a close encounter with venus
Mercury's original circular orbit
Sun
Mercury's orbit becomes elliptical
Venus's orbit

Astronomy: Elisabeth Rowan

Earth hard enough to knock it onto one of the unstable paths?

To answer this question, astronomers have had to confront the beast. They must take up Newton's challenge and directly compute the future of the solar system.

Silicon Intelligence

While the future history of the solar system will never be solved directly by the human intellect, silicon intellect is another matter. Computers can take the equations which govern planetary orbits and solve them one tiny step at a time, billions of times per second. In this way, astronomers can build a "simulation" of the solar system and ask if it is chaotic.

Jack Wisdom and Gerald Sussman of the Massachusetts Institute of Technology helped pioneer this method in the 1980s after constructing a special-purpose computer called the Digital Orrery. An orrery is a mechanical ball-and-stick model of the solar system. With their computerized orrery, they performed a series of ground-breaking calculations which, for the first time, tracked the motions of the planets across astronomical timescales.

Their first study focused on a reduced solar system consisting of only the outer five planets. Fewer planets meant less computational time and that meant they could run their simulations long enough to make a startling discovery. "After 845 million years of evolution," says Wisdom "we saw clear signs that Pluto's orbit was chaotic" — meaning that slight variations in its initial position led to very different future orbits. For example, an uncertainty in Pluto's position of one inch will put the planet on the opposite side of the sun in 100 million years. This was a profound result because, as Wisdom puts it, "A chaotic system is inherently unpredictable." Wisdom and Sussman were the first to show that chaos does indeed have a home in our solar system.

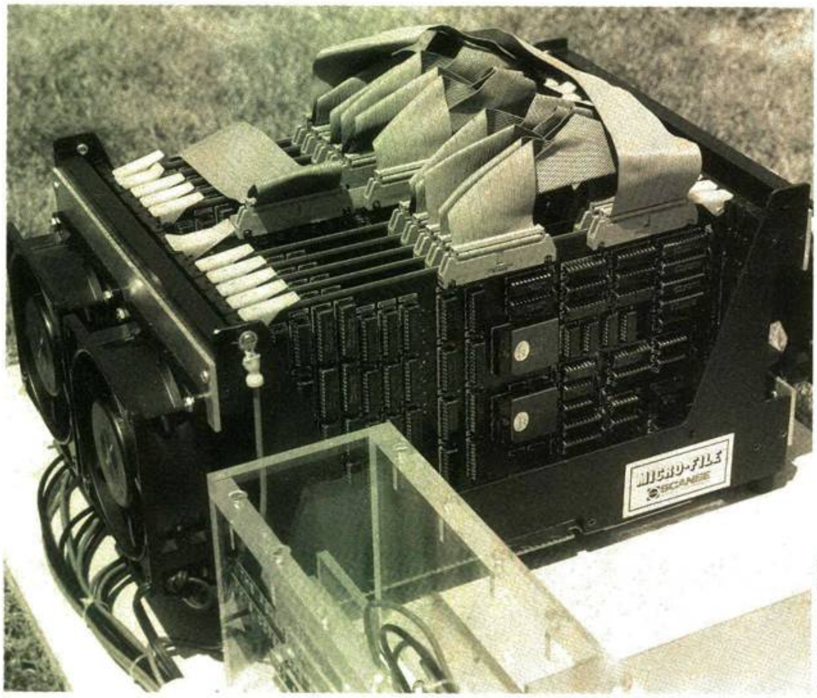
Wisdom is careful, however, to distinguish between chaos and what he calls "wild chaos." "Wild chaos," he says, "is when a planet behaves in an obviously irregular manner. A system can be chaotic but not behave very irregularly. The planet may only move irregularly in a narrowly confined region of space. Without an appropriate microscope the motion does not look very chaotic even though it is completely unpredictable." According to Wisdom, this seems to be the case for Pluto. "Our experiments indicate it is chaotic, but the orbit does not look particularly irregular." In other words, while chaos makes Pluto's orbit unpredictable, it may not doom Pluto itself.

Planets may not get permanent membership in their solar systems

The Search for Wild Chaos

During the same period when Wisdom and Sussman were simulating the outer solar system, French astrophysicist Jacques Laskar of the Bureau des Longitudes in Paris developed an approximate method to study the long-term evolution of the entire solar system. Instead of following each planet as it revolved around the sun, Laskar

BOTTOM RIGHT: An orrery symbolizes Newton's clockwork conception of the solar system, an idealization rendered outdated by chaos. **BOTTOM LEFT:** Jack Wisdom and Gerald Sussman's "digital orrery" can track the motions of planets hundreds of millions of years into the future.



Gerald Sussman (MIT)

Adler Planetarium and Astronomy Museum, Chicago, Illinois looked directly at the structure of the orbits themselves. He envisioned the orbits as flexible rings that can be pulled, pushed, and deformed by the mutual gravitational forces of the planets. Laskar's method allowed him to follow the entire solar system for hundreds of millions of years. His results implied that chaotic irregularity would appear in the orbits of many planets, particularly Mars's and Mercury's. But was this irregularity wild chaos?

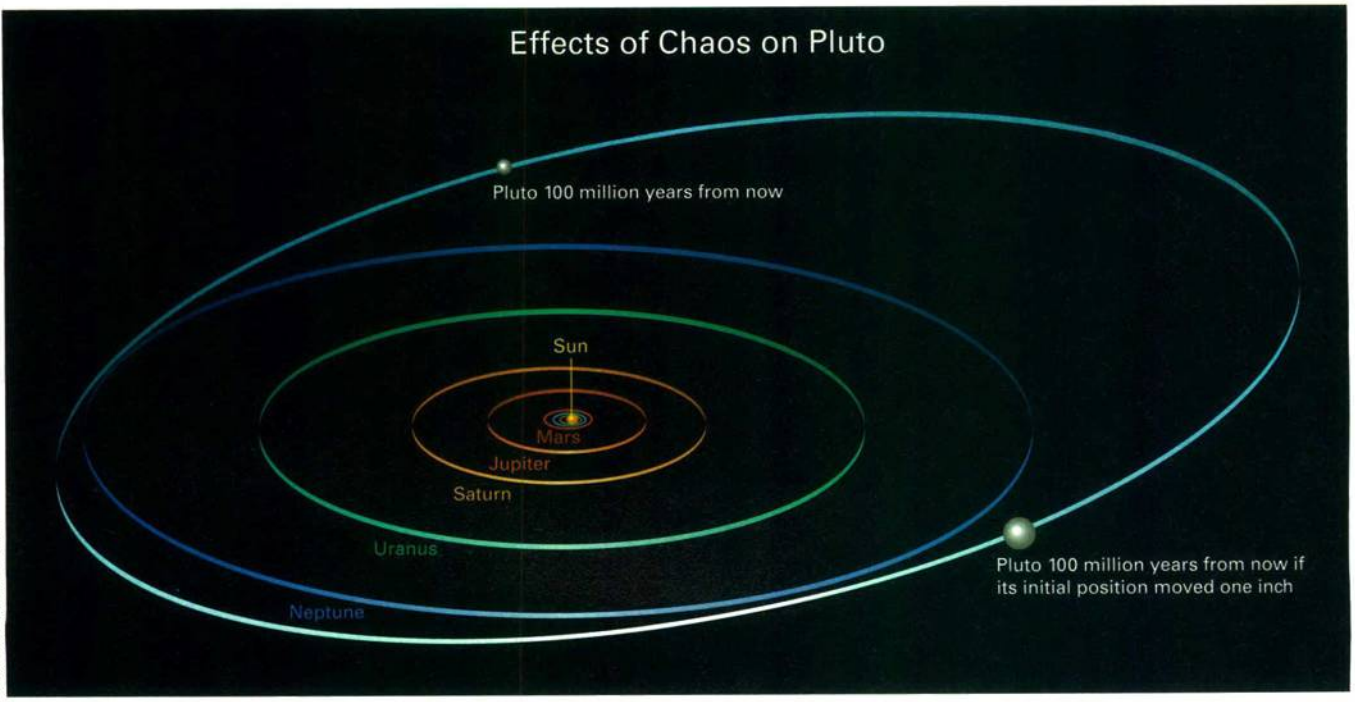
That question forced astronomers back to Wisdom's and Sussman's "brute force" approach. Simulating the whole solar system for billion-year timescales strains the intellect of even the most super of supercomputers. Tom Quinn of the University of Washington was part of a team that completed another long-term simulation of the solar system. "I actually became interested in building the computer code because of the issue of climate change," says Quinn. "Our first study went three million years into both the past and the future to understand the effect Earth's orbit had on climate."

It was Quinn's second study that attempted to confirm Laskar's predictions, taking the solar system six million years into the future. "We couldn't go any further," says Quinn. "All the little steps the computer makes force errors to build up in the simulation. By the end, it gets so bad you can't say on which side of the sun Mercury is located." In spite of these limits, Quinn's calculation confirmed that Laskar was right: The motion of the inner planets — including Earth — is chaotic in a technical sense. However, six million years was not long enough to see if any of the planets were wildly chaotic.

In the last five years, Wisdom and Laskar have each exploited advances in computers to push the envelope of their calculations out to billion-year timescales. Together they have found strong evidence that the orbits of both Mars and Mercury may be chaotic in the wild sense. "On a billion-year timescale, the motion of Mercury and Mars is distinctly irregular," says Wisdom.

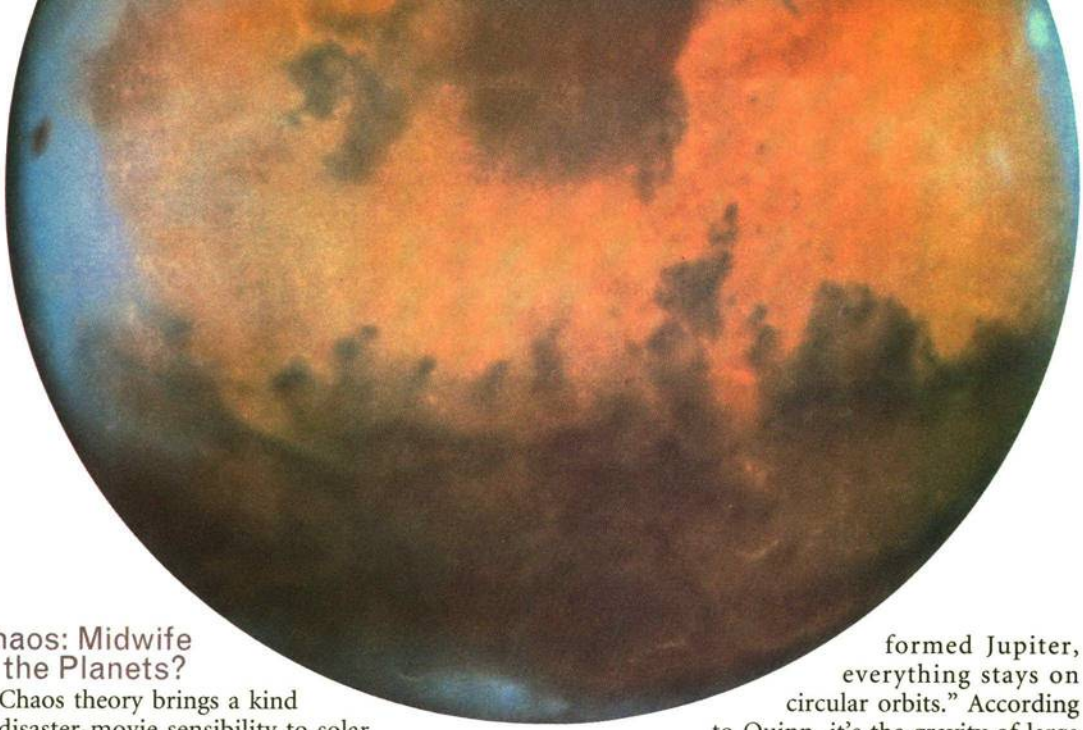
Says Quinn: "Based on Laskar's simulations, there is something like a one-in-a-thousand chance that we may lose Mercury in the next five billion years." Quinn points out that Mars, too, has a chance of getting thrown out after a close encounter with Earth. But he adds, "If Mars ever intersects the orbit of Earth, it's not necessarily Mars that gets kicked out. Earth could get kicked out as well. But because Earth is more massive than Mars, it's more likely that Mars will get kicked out. It depends on the details of their orbits, so Earth is not entirely safe."

More important for long-term investment strategies, however, is the apparent stability of Earth's and Venus's orbits. While they are chaotic in the formal sense, they do not appear to exhibit the more fearsome wild chaos, primarily because their orbits are nearly circular, whereas Mercury and Mars have distinctly elliptical orbits, which increases their gravitational interaction with the other planets. It is still too early, however, to say precisely what the fate of the solar system's inhabitants will be. "We are still in the first phases of these kinds of studies, and much of the work depends on improving computational power," says Lake. "Now we understand that the solar system is chaotic, but the critical details are all but unknown. It takes a computer close to a trillion steps to perform one of these calculations. Even to a supercomputer, that is really quite a lot. To answer these stability questions, we must push to the limits of what our computers can do."


Effects of Chaos on Pluto
Pluto 100 million years from now
Sun
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto 100 million years from now if its initial position moved one inch

Chaos at work: An uncertainty of one inch in Pluto's position will put it on the opposite side of the sun in 100 million years.

Astronomy: Elisabeth Rowan



There's a slight chance that Mars's orbit will someday cross Earth's. If so, one of the two planets could get tossed out of the solar system, more likely it would be Mars due to its lower mass.

Philip James (University of Toledo), et al., and NASA

Chaos: Midwife to the Planets?

Chaos theory brings a kind of disaster-movie sensibility to solar system studies, providing images of innocent planets being tossed into space, or asteroids smashing into Earth. When it comes to forming new solar systems, however, chaos may take on a kinder, gentler face. It may even play a central role in the birth of planetary systems. "Up to now in the evolution of the solar system, chaos has really been acting in our interest," says Lake. "Chaos may be needed to get planet formation started, and after planets form, it may also be a principle cleansing mechanism, a means for clearing the solar system of a lot of post-formation debris."

Astronomers believe planets coalesce inside disks of gas and dust left over from the creation of new suns. The most popular theories hold that planets start as "planetesimals," small, orbiting clumps that grow by colliding with other clumps (see "From Pebbles to Planets," February 1998). One of the problems with this story is the difficulty in getting enough clumps near the same orbit so they can collide. The process takes too long if gravity alone acts to gather new material. The instability that accompanies chaotic dynamics can aid the process by scattering newly-formed clumps out of their original orbits and into the so-called "feeding zones" of the planetesimals. This is an attractive idea because it can solve two problems at once, explaining both planet formation and the paucity of material between the planets in the present-day solar system.

Matt Holman, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics, says, "We see that there are large regions of the present solar system that are empty. These may be zones of chaos where no stable orbits exist." Holman explains that in a young system, material will get tossed out of these zones into the path of newly-formed planets.

Massive planets play a special role in the process. "You may need a Jupiter to stir the pot," says Quinn. "In a young system, without a newly formed Jupiter, everything stays on circular orbits." According to Quinn, it's the gravity of large planets that perturbs the orbits of the clumps and scatters them into the paths of planetesimals.

For Lake, the dependence of orbital chaos on Jupiter-sized objects may have profound consequences for future NASA searches for extrasolar planets. "Currently our technology is such that the best we can hope for is to find big Jupiter-sized planets. But Jupiters, we have found, are the agents of chaos. They may be a necessary condition for forming smaller Earth-sized worlds."

There is a chance that we may lose Mercury in the next five billion years

New Visions

There have always been images in science that serve as a lens for our view of the universe. The clockwork solar system, planets tracing out perfect eternal orbits, has long symbolized the perfect harmony and reason we attributed to the universe of science.

Following on the heels of advances in computers, chaos theory is changing that vision of the solar system. In the wake of chaos theory, our understanding of planetary motion has been reformed from that of an eternal clock to a dynamic, infinitely complex entity.

Adam Frank is an astrophysicist at the University of Rochester in upstate New York. His most recent article for Astronomy, *"Angry Giants of the Universe," appeared in the October 1997 issue.*

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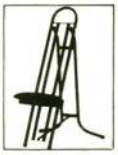

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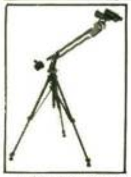

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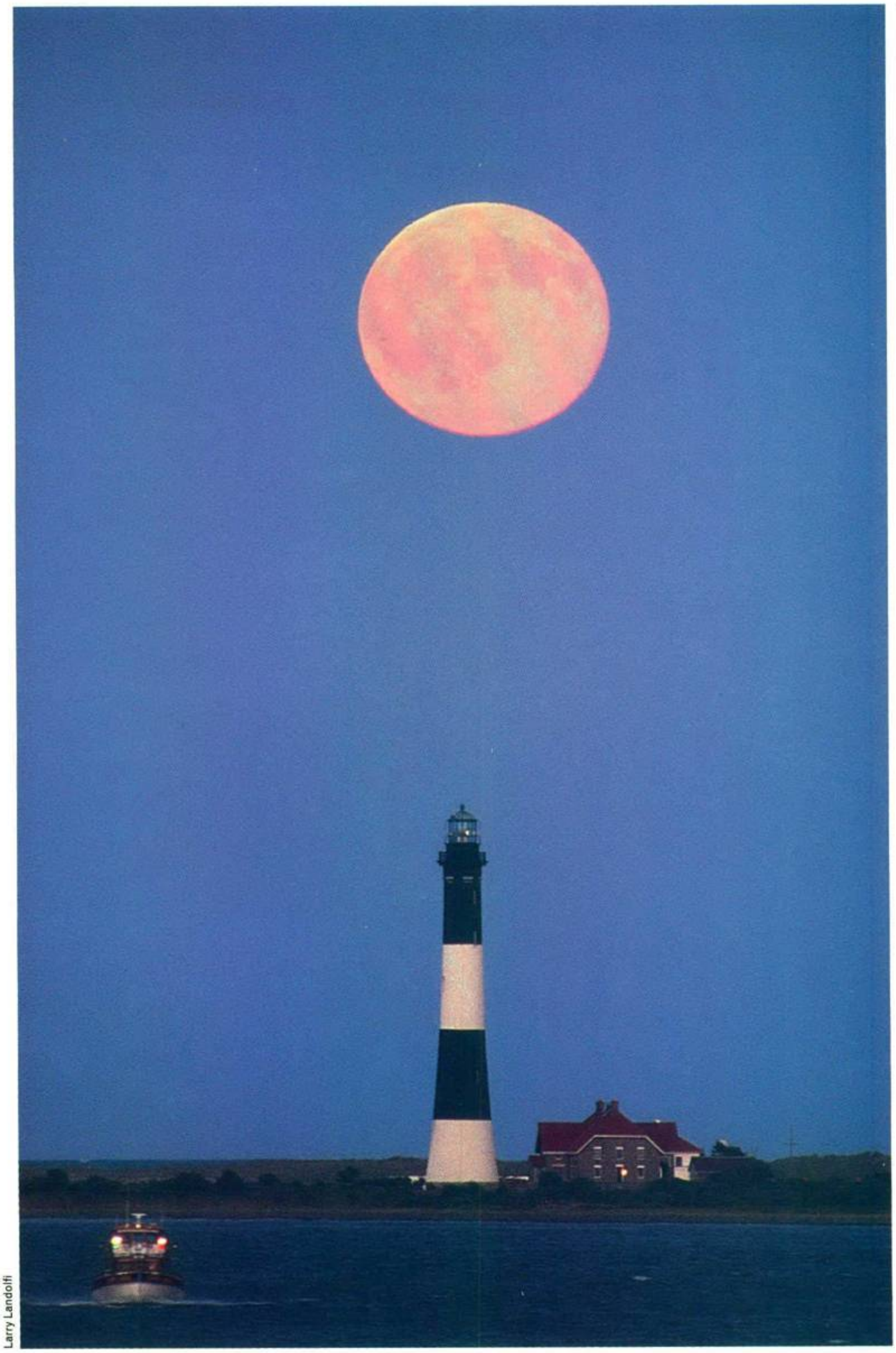
THE SKY SHOW

Dim, remote Pluto reaches opposition this month. It beckons the tenacious observer to seek out its lair. For those in want of a lesser challenge, bright morning planets can be sought in the glow of dawn.

by Martin Ratcliffe and Alister Ling


Larry Landolfi

May is a month of transition. A time when the cloudy skys and showers of April are replaced with the flowers and spring galaxies of May. As the seasons warm and the nights grow shorter, we dust off our telescopes to catch the best the season has to give.

The first offering of May is distant **Pluto**. This tiny, indistinct world reaches opposition on May 28. Questions about its planetary status will undoubtedly arise as observers begin to hunt for our most elusive neighbor. Is Pluto truly a planet, or is it simply the largest of the Kuiper Belt objects? Its unusual orbit, small size, and icy composition have led astronomers to speculate on Pluto's interesting past.

The planets in our solar system orbit the sun in the same general plane. Their orbits are inclined no more than 7° from the ecliptic (the apparent path the sun takes through our sky as we make our yearly orbit around it). The exception to the rule? Pluto. This small icy world has a highly inclined orbit (17°) that takes it beyond the region the other planets roam. Pluto's orbit also sneaks inside Neptune's. In 1979,

The full moon of May is called the Planting or Milk Moon. This month's full moon occurs on the 11th, but start keeping watch earlier. By observing the moon on several different days of the month, you may be able to detect the lunar libration described in this month's Lunar Limbo Dance.

3 First quarter moon is at 6:04 a.m. EDT

4 Mercury is at greatest western elongation (27°), 1 p.m. EDT

5 Eta Aquarid meteor shower peaks (page 68)

8 The moon is at apogee (252,190 miles from Earth), 4:56 a.m. EDT

11 Full moon is at 10:29 a.m. EDT

12 Mercury passes 0.8° south of Saturn, noon EDT (page 68)
Mars is in conjunction with the sun, 4 p.m. EDT

17 The moon passes 3° north of Neptune, 3 a.m. EDT
The moon passes 3° north of Uranus, 11 p.m. EDT

19 Last quarter moon is at 12:35 a.m. EDT

20 The moon passes 0.4° south of Jupiter, 7 p.m. EDT

22 The moon passes 1.7° south of Venus, 6 p.m. EDT

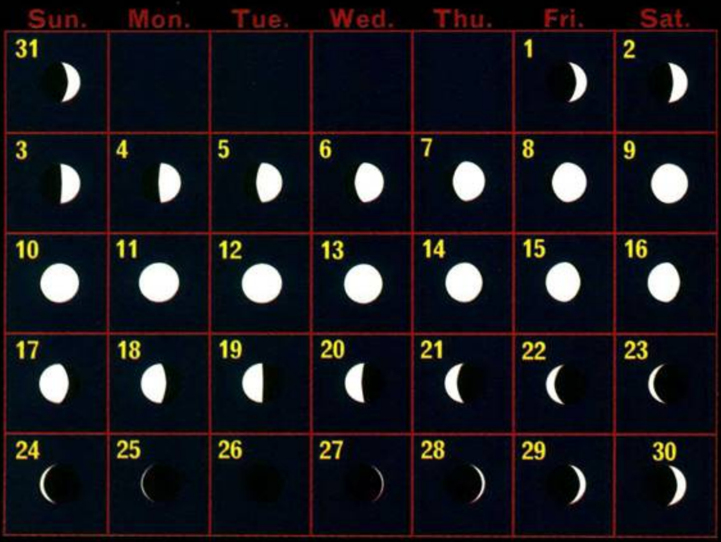
23 The moon passes 1.7° south of Saturn, 4 a.m. EDT
The moon is at perigee (224,725 miles from Earth), 8:02 p.m. EDT

24 The moon passes 3° south of Mercury, 7 a.m. EDT

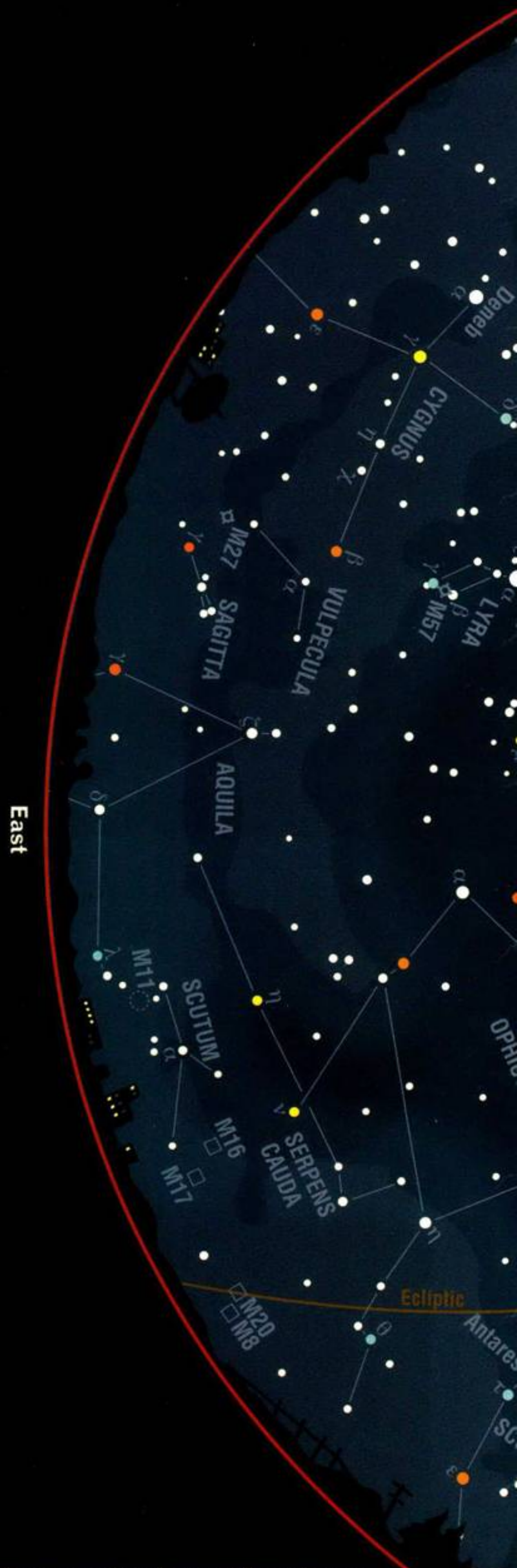
25 New moon is at 3:32 p.m. EDT

28 Pluto is at opposition, 1 a.m. EDT
Venus passes 0.3° north of Saturn, 10 p.m. EDT (page 68)

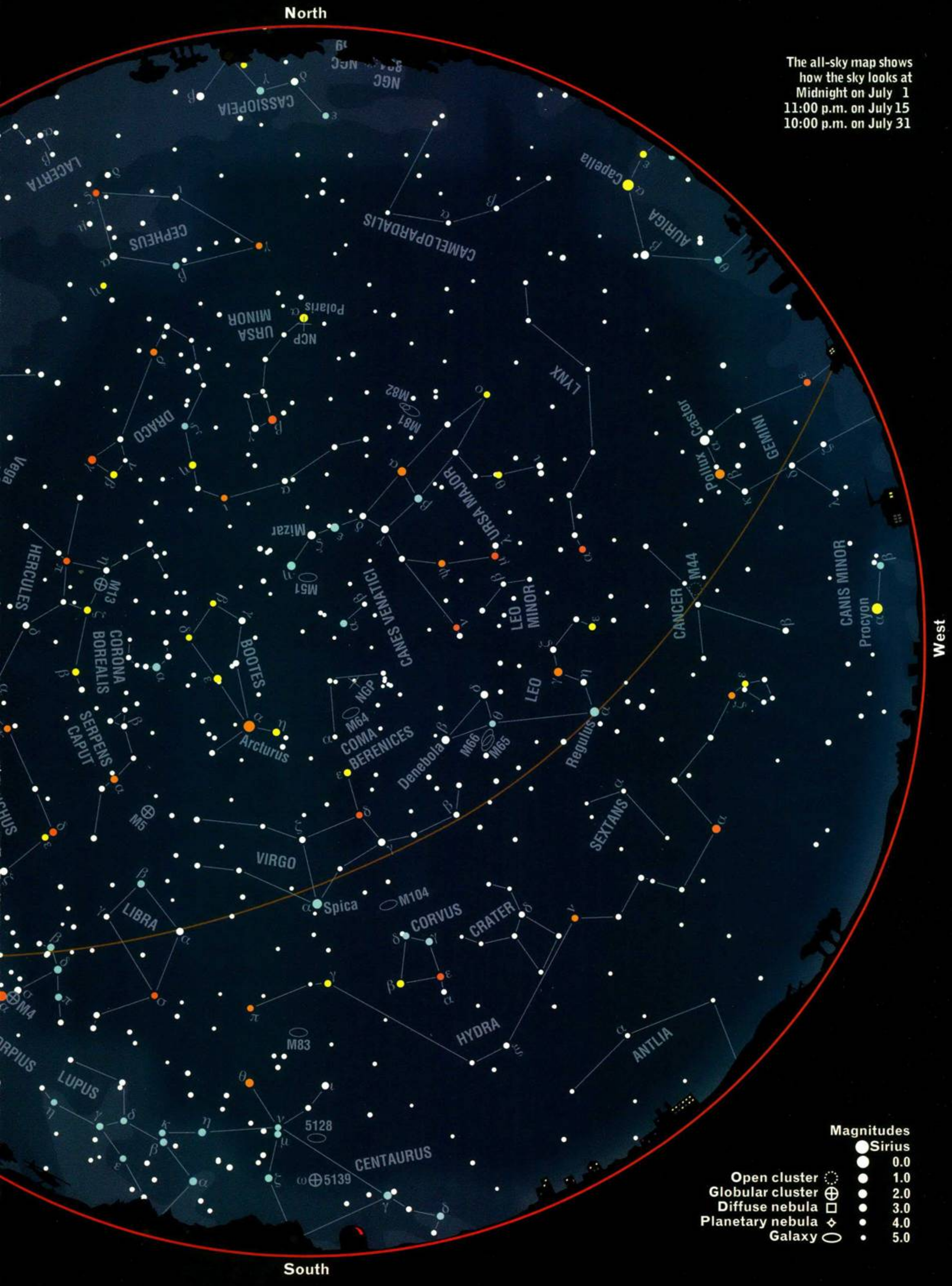
31 The moon passes 1.0° south of Regulus, midnight EDT



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

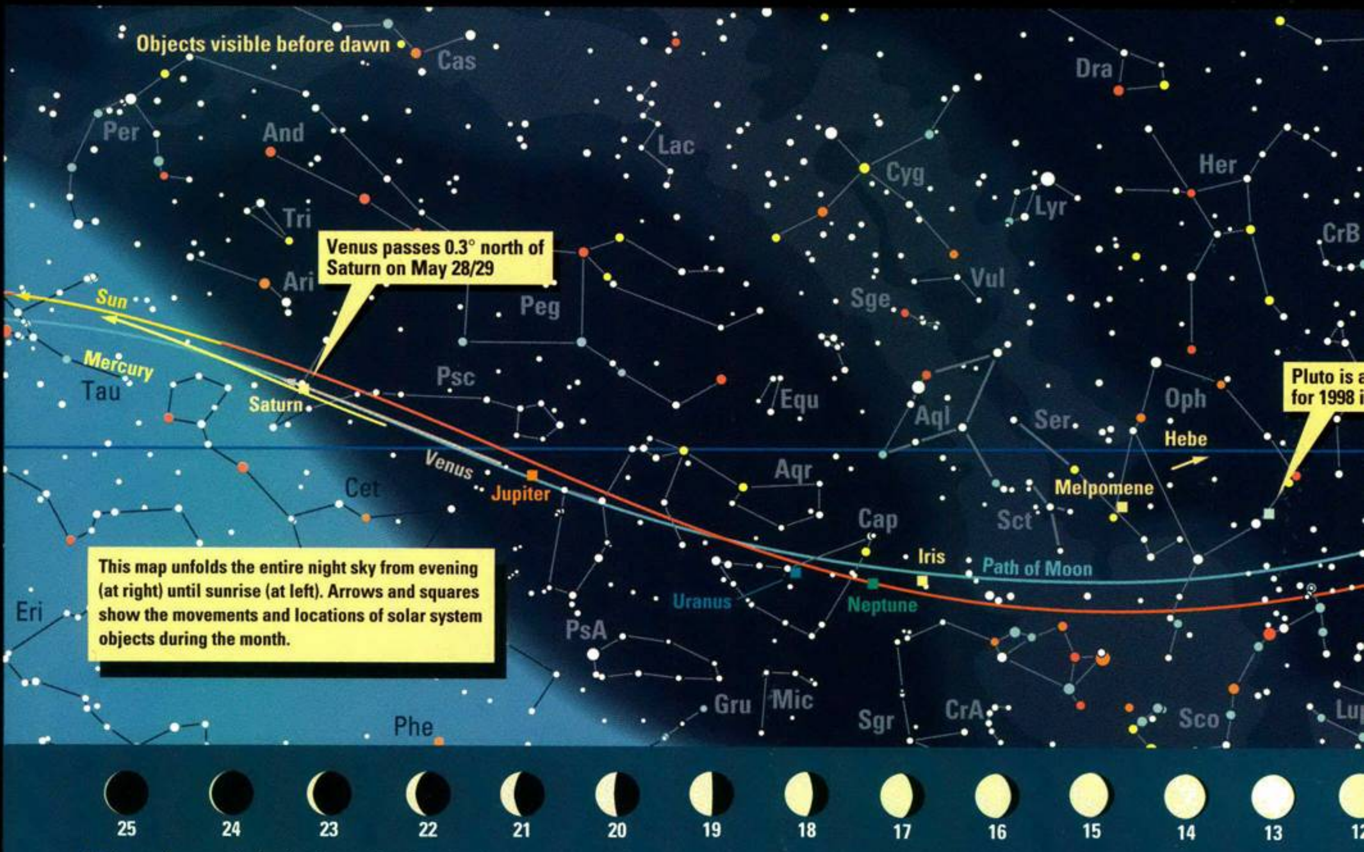


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
CASSIOPEIA
NGC 884
NGC 869
LACERTA
CEPHEUS
CAMELOPARDALIS
Capella
AURIGA
URSA MINOR
Polaris
NCP
DRACO
M82
M81
LYNX
Castor
Pollux
GEMINI
Vega
URSA MAJOR
Mizar
M51
HERCULES
M13
CANES VENATICI
LEO MINOR
CANCER
M44
CANIS MINOR
Procyon
West
CORONA BOREALIS
BOOTES
NGP
LEO
Arcturus
M64
COMA BERENICES
Denebola
M66
M65
Regulus
SERPENS CAPUT
M5
SEXTANS
VIRGO
Spica
M104
LIBRA
CORVUS
CRATER
M4
HYDRA
M83
ANTLIA
LUPUS
5128
CENTAURUS
5139
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
Midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31

THE PATH OF THE PLANETS


Objects visible before dawn
Cas
Per
And
Lac
Dra
Cyg
Lyr
Her
CrB
Tri
Ari
Peg
Sge
Vul
Sun
Mercury
Tau
Saturn
Psc
Equ
Aql
Ser
Oph
Hebe
Venus
Jupiter
Cet
Aqr
Melpomene
Cap
Sct
Iris
Path of Moon
Eri
Uranus
Neptune
PsA
Gru
Mic
Sgr
CrA
Sco
Lup
Phe
25
24
23
22
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19
18
17
16
15
14
13
12

Venus passes 0.3° north of Saturn on May 28/29

Pluto is a
for 1998 i

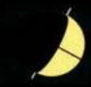
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

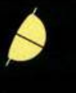
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

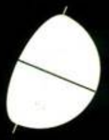
10"

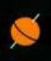
S W E N

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUP
Date	May 1	May 15	May 15	May 15	Ma
Magnitude	0.7	0.0	–4.1	1.3	–
Angular Size	8.6"	6.7"	15.9"	3.8"	36
Illumination	37%	59%	70%	100%	9
Distance (AU) from Earth	0.778	1.001	1.051	2.490	5.
Distance (AU) from Sun	0.464	0.423	0.728	1.480	4.
Right Ascension (2000.0)	0h56.6m	1h55.4m	0h49.7m	3h24.3m	23h3
Declination (2000.0)	3°08'	8°42'	3°23'	18°42'	–4



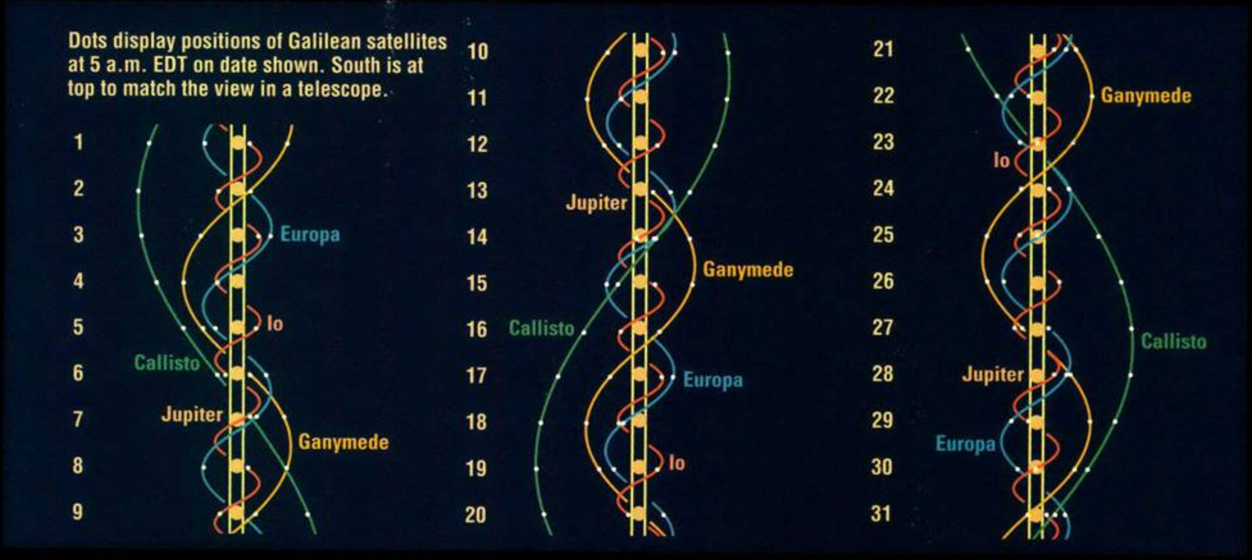


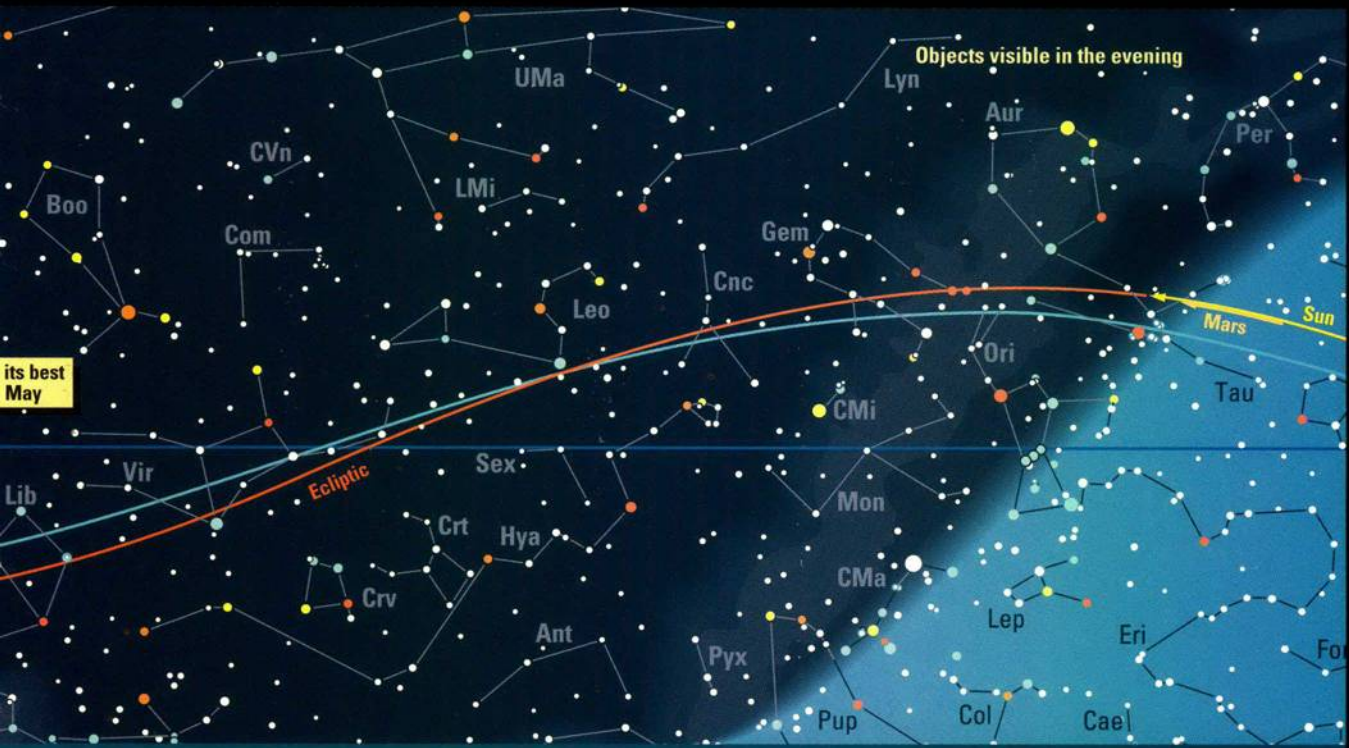


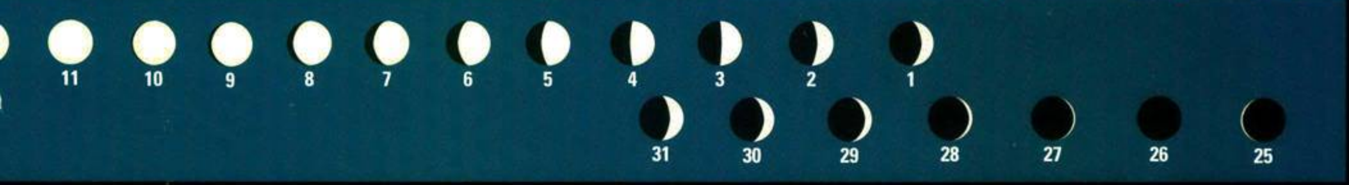


JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 a.m. EDT on date shown. South is at top to match the view in a telescope.




Objects visible in the evening
UMa
Lyn
Aur
Per
CVn
LMi
Boo
Com
Gem
Cnc
Leo
Sun
Mars
Ori
its best
May
Tau
CMi
Vir
Sex
Lib
Ecliptic
Mon
Crt
Hya
CMa
Crv
Lep
Ant
Eri
Pyx
Fo
Pup
Col
Cael


11
10
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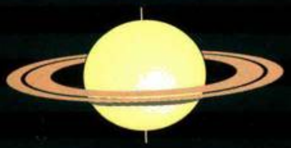
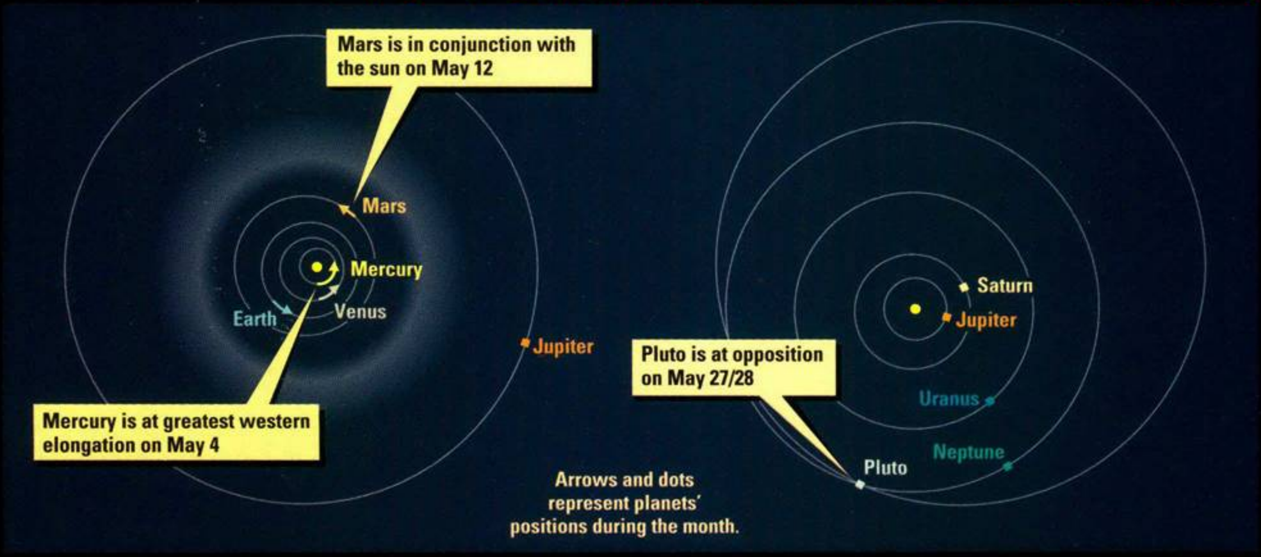


TER	SATURN	URANUS	NEPTUNE	PLUTO
y 15	May 15	May 15	May 15	May 15
.2	0.4	5.8	7.9	13.7
6"	16.3"	3.6"	2.3"	0.1"
%	100%	100%	100%	100%
85	10.221	19.638	29.750	29.099
90	9.330	19.860	30.141	30.062
2.7m	1h44.6m	21h01.7m	20h17.3m	16h29.3m
06'	8°23'	–17°36'	–19°20'	–9°13'

THE PLANETS IN THEIR ORBITS


Mars
Mercury
Earth
Venus
Jupiter
Saturn
Jupiter
Uranus
Neptune
Pluto

Mars is in conjunction with the sun on May 12

Mercury is at greatest western elongation on May 4

Pluto is at opposition on May 27/28

Arrows and dots represent planets' positions during the month.

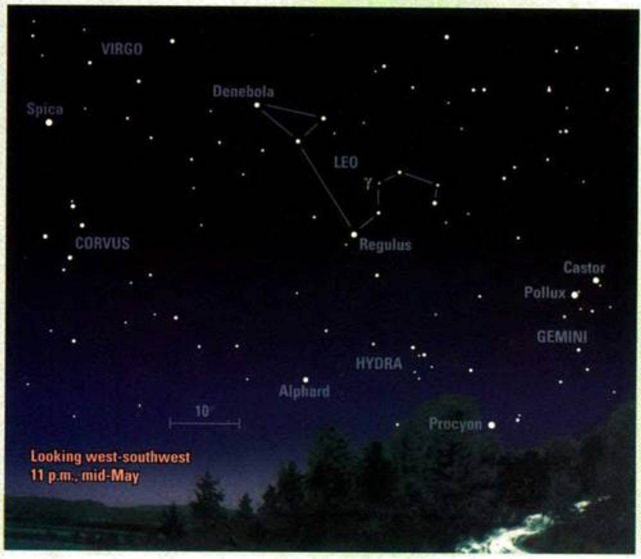
FIRST VIEWS: Golden Gamma

Arguably one of the finest double stars, Algeiba or Gamma (γ) Leonis is an enticing target for both the novice and experienced observer.

Unlike Cygnus the Swan's beautiful topaz and sapphire gem of Albireo (Beta [β] Cygni), Gamma Leonis is a study in topaz and gold. The primary star has a magnitude of 2.4 and is separated by a comfortable 4.5" from its magnitude 3.4 companion. Yet the pair's separation is much smaller than the 34.3" between Albireo's twosome. To split Gamma Leonis, your scope must be at a magnification of 150x or more.

The sky is full of wonderful double stars. Near to Gamma Leonis is Gamma Virginis. This double holds a pair of identical white stars. Don't forget to point your telescope toward them as well.

While you are in the area, take in the view of Regulus. Though it too is a binary star, it's a greater challenge. The companion has a seperation of 177" and a magnitude of only 4.9 — 400 times fainter than Regulus.



Looking west-southwest
11 p.m., mid-May

All illustrations by *Astronomy*: Elisabeth Rowan

Pluto entered that segment of its orbit, begining a 20-year period in which Pluto became the eighth planet from the sun. Whatever the answer to its nature and origin, Pluto represents the greatest planetary challenge to the backyard observer.

At magnitude 13.7, just finding Pluto is an achievement. The first requirement in completing this deed is a great deal of patience. Add a dark, moonless sky with little light pollution, a good star chart, at least an 8-inch telescope, and you're well on your way to sighting Pluto.

Pluto can be found lurking in Ophiuchus this month. The planet is just over a degree northwest of 3rd-magnitude Zeta (ζ) Ophiuchi. Use a 14th-magnitude star chart of this region to help you find Pluto. Once you're at the telescope, try to find some of the fainter stars on the chart. If you see these stars, you'll have a good chance of seeing Pluto. Start off by carefully sketching the starfield around Zeta Ophiuchi. A few days later, observe the same region again. If you see an object that has moved relative to the starfield, you've found Pluto.

Before May 28, there are no planets in the evening sky. **Mars** finally reaches conjunction on May 12 and is therefore hidden behind the sun. This means that the principal planetary action takes place in the morning sky, but let's first survey the evening sky's wonders.

The moon is a helpful guide to the starry realm during the first week of May. The almost first quarter moon passes south of the Beehive Cluster (M44) in Cancer the Crab on May 2. Lying well below the moon on the same evening is the brilliant white 1st-magnitude star Procyon in Canis Minor the Little Dog. To the far right of the moon are two stars that represent the heads of Gemini the Twins, Castor and Pollux.

Castor (Alpha (α) Geminorum) and Pollux (Beta (β) Geminorum) are two stars that easily fit into the same field of view in a pair of 7x50 binoculars. Having them in the same field lets the observer appreciate their contrasting color. Brighter Pollux has a rich orange-yellow hue while Castor is a cool bluish-white.

Another good color contrast can be found in Gemini's feet. Eta (η) and Mu (μ) Geminorum are both red giant stars with a characteristic reddish-orange hue, while Gamma (γ) is bluish-white. Unlike the close pairing of Castor and Pollux, Eta and Mu are some 8° north of Gamma.

Being red giant stars, Eta and Mu are also variable stars. Mu's luminosity variation is too slight to easily detect. It ranges from magnitude 2.8 to 3.0. Eta's variance is easier to detect. It ranges from a magnitude of 3.1 to 3.9 in a period of about 233 days.

At this time of the year, you can find the two stick figures of Gemini standing upright on the northwestern horizon by midnight, the stars Castor and Pollux marking the heads of the twins with the same names. The stars Kappa (κ), Upsilon (υ), Iota (ι), Tau (τ), and Theta (θ) mark the arms of the twins, while the stars below their arms mark their torsos and legs.

Beyond Gemini and Cancer is Leo the Lion. This constellation holds the mystique of kingly power. Leo was the mythological lion of Nemea. Nemea is a town that was terrorized by the two-headed lion that lived in a cave above the city. As one of his tasks, Hercules was despatched to slay the beast and rid Nemea of this menace. Fortunately for Leo, his hide was impenetrable. No sword or knife could get through his skin. When Hercules shot an arrow at Leo, it simply bounced off. Hercules then tried to pummel Leo with his club. A wrestling match ensued. Hercules wrapped his massive arms around the lion's throat and held his tight grip until the beast was dead. Having completed his task, Hercules carried the lion away in triumph. He later used Leo's razor-sharp claws to cut the pelt from the carcass. Hercules is often depicted wearing a lion's pelt as a cloak, the creature's gaping mouth hovering over his own head.

The heart of Leo the Lion, the magnitude 1.4 star Regulus, can be found less than 5° to the west of the waxing gibbous moon on May 5. By May 8, an almost full moon lies just over 5° north of 1.0-magnitude Spica, in Virgo the Maiden. Virgo represents the goddess of the harvest, Demeter, and the star Spica is typically depicted as an ear of wheat she holds in her hand. The moon then moves to nearly 10° north of Antares on May 12. This red supergiant marks the heart of Scorpius the Scorpion.

After the moon has left the evening sky (during the latter half of the month) search out a few of the more than 250 galaxies that can be seen in a small backyard scope. This unusually high number is due to the fact that the Milky Way is not blocking our view of the more distant universe. At this time of year, we are looking directly out of the plane of our galaxy. In addition, large galaxy clusters, such as the Virgo and Coma clusters, also can be found in this direction.

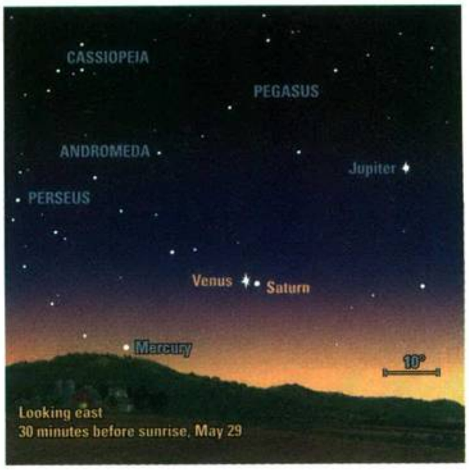
The attractive but faint constellation Coma Berenices inhabits the region between Virgo and Ursa Major. These 4th- and 5th-magnitude stars were once referred to as Leo's tail. It was the Greek astronomer Eratosthenes who labeled the group after Egyptian Queen Berenice's hair. The queen was wife to King Ptolemy III. The myth begins during a war in which Ptolemy

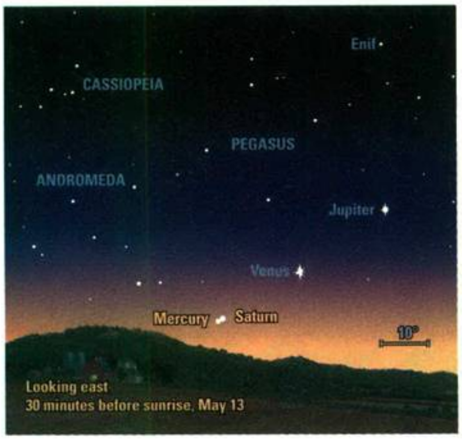
Another Meeting of a God and Goddess

Last month we saw a spectacular conjunction between Jupiter and Venus. This month, as Venus falls back toward the glare of the rising sun, Saturn climbs out as if to greet her. The twosome closes to within a moonwidth (0.5°) apart on May 29.

Early in the month, you need to keep your eyes and binoculars trained on the morning sky. On May 13, Saturn and Mercury lie only 1° apart. Take this opportunity to compare their colors. Some observers say they are both yellow. What do you think? As for their brightness, Mercury wins that competition. It edges out Saturn by a scant 0.4 of a magnitude. You can find elusive Mercury gleaming above the eastern horizon at magnitude 0.1 on May 13.

Get out your scope and view these planets with some power. Saturn's rings will have opened up a few degrees compared with their position last year. Venus will show a waxing gibbous phase (70 percent lit), while Mercury's waxing phase moves from a half disk to a thick gibbous by month's end.



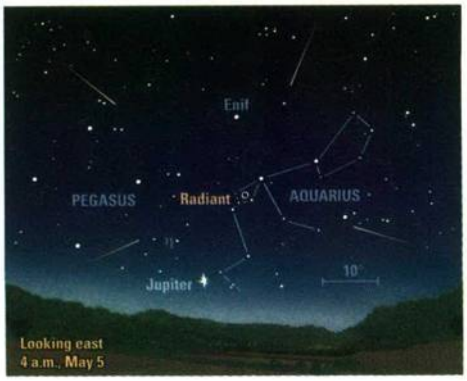


Halley's Children

Fans of Halley's Comet look forward to the Eta (η) Aquarid meteor shower every year. It's a time when Earth's gravity scoops up the dust ejected from this comet's previous sojourns to the inner solar system. Once in our atmosphere, these particles burn quickly, creating swift streaks across our night sky.

During the first week of May, we encounter the meteoroid swarm relatively face on. This produces "shooting stars" traveling at 40 miles per second. The shower's peak, on the night of May 4/5, arrives just 2 days after the first quarter moon. The typical Northern Hemisphere rate of 20 meteors per hour will be diminished by the brightened sky to 10 to 15 meteors per hour. Higher numbers can be expected in the Southern Hemisphere and during the early hours before dawn for those in the Northern Hemisphere. At that time, the shower's radiant or source is high in the southern sky.

Grab a deck chair, sleeping bag, and hot drink, lean back, and enjoy a relaxing observing experience.



fought the Assyrians. To assure the king's safe return, Queen Berenice promised to sacrifice her long hair to the goddesses. When Ptolemy returned unscathed, the queen duly cut off her hair and placed it in a vault. When the hair mysteriously disappeared, the court astronomers declared that Zeus had placed it among the stars.

Start your tour of Coma Berenices with two of Charles Messier's finest objects, M53 (NGC 5024) and M64 (NGC 4826). M53 is a 5th-magnitude globular cluster that rests a mere 0.5° north of Alpha (α) Comae Bernenices. M64 is also known as the Blackeye Galaxy, so called because of a particularly dark dust lane that lies near its center. This unique feature is visible in most small amateur scopes. The 8.5-magnitude galaxy was discovered in 1779 by German astronomer Johann Bode.

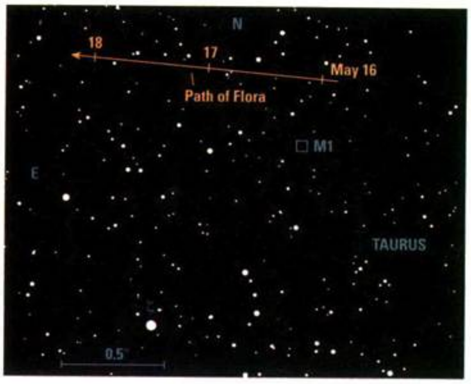
Another fine galaxy, and curiously not listed by Charles Messier, can be found 6° northwest of M64. It's the great edge-on spiral galaxy, NGC 4565. At low power this magnitude 9.6 galaxy looks like a pencil smudge 15' long and just 2' wide. Try spotting the prominent dust lane that divides the galaxy in half.

North of Coma Berenices rests Canes Venatici the Hunting Dogs. This tiny constellation represents two dogs held on a leash by Bootes the Herdsman. The Polish astronomer Johannes Hevelius created Canes Venatici in 1687 from stars that were previously part of Ursa Major the Great Bear. The pair is often depicted yapping and snapping at the heels of the bear. Ursa Major can easily be found directly overhead in the early evening.

Winter Sky's Flora

Larry Myers

STScI/NGS POSS



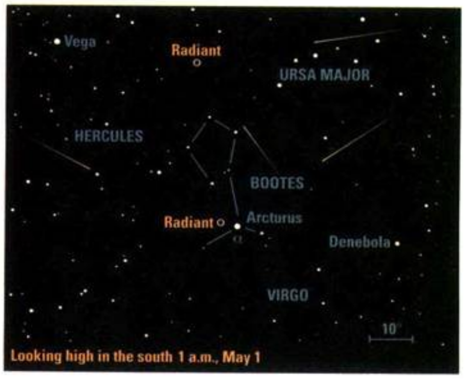
As if leaving winter behind, asteroid 8 Flora moves quickly away from Taurus and into Gemini this month, passing swiftly by the Crab Nebula (M1).

Discovered in 1847 by the British observer J. R. Hind, 8 Flora is a moderately sized hunk of rock, some 90 miles (140 km) across. Because it is near the far point of its orbit (aphelion), it shines feebly at magnitude 10.9.

On the nights of May 16 and 17, Flora skims some 30' — a lunar diameter — to the north of the Crab Nebula. Try to detect its motion during the course of an hour. To do this, make a sketch of the field, wait an hour, and then come back to it.

Later in the month, Flora comes within grappling distance of the splashy open cluster NGC 2129. Take this opportunity to see one of the sky's lesser known sights.

The Herdsman's Lost Sheep



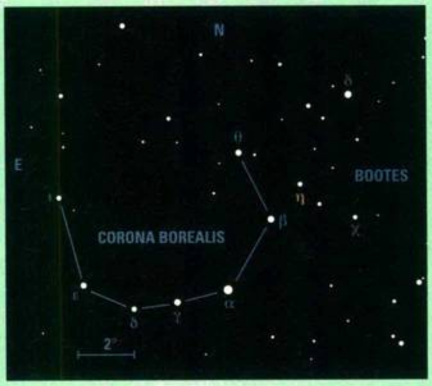
Looking high in the south 1 a.m., May 1

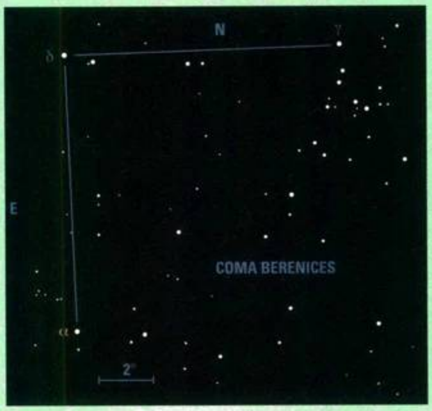
Overshadowed by the more famous Eta (η) Aquarids, the Bootids of early May have fallen off some lists of active meteor showers. With some simple skywatching, you can help to resurrect this enigmatic shower.

The Bootids, for me, bring back fond memories of a past observing session where a few friends and I "discovered" this shower. We were sharing a telescope and therefore needed to wait patiently for a turn at the eyepiece. During this downtime, we dutifully watched the sky. It was easy to recognize that the graceful streaks causing us to "oooh and aaah" shared a common origin somewhere in Bootes. When I later checked A. F. Cook's *Working List of Meteor Streams*, I found two weak showers listed together, the Alpha (α) Bootids and Phi (ϕ) Bootids — the International Meteor Organization lists only the Alpha Bootids. These two weak meteor streams have radiants that are fairly high during the time of peak activity, so you may see more Bootids than Aquarids. In fact, half of the Aquarids occur below the horizon for far northern observers. Another reason to look for the Bootids is the position of the moon. The shower's peak occurs on May 1, when the moon is not yet at first quarter. The moon sets around the time that the shower's radiant is at its highest point in the sky. The fact that the shower peaks on a weekend also increases your chance of spotting some meteors during your regular observing time.

The Bootids are slow (9 miles per second) compared to the better known Perseids (40 miles per second). The radiants for the Bootids are 14h28m 19°20' and 15h40m 51°10' (2000.0).

OBSERVER'S CHALLENGE: Devilishly Difficult Doubles





A challenge can test more than the skill of the observer — in this case, we test the limitations of our atmosphere. Close double stars have intrigued astronomers for centuries. Professionals study them in order to deduce stellar masses and to test their theories, while amateurs chase them to test their optics as well as their eyesight.

The primary factor in observing doubles is the steadiness of the atmosphere — no picturesque twinkling allowed. A slight turbulence can blur a pair of stars into a single mush. Stagnant air masses are more common this time of year. It's those hazy nights when the evening temperature barely falls that are the steadiest.

To set the record straight on a frequently repeated myth, haze and pollution do not help make an air mass stable. It is the stable high pressure air mass with gentle upper winds that causes haze and pollution to be trapped at lower levels.

Eta (η) Coronae Borealis sets the stage for challenging a 5-inch scope and its owner. The gap between its 5.6- and 5.9-magnitude yellow stars is 1". To successfully split the pair, increase the magnification to at least 250x. This magnification may only yield the characteristic "figure 8" formed by the stars' two Airy disks. These disks are created by the wave nature of light and not by the stars and their proximity to one and other. The Airy disk is named for Sir Charles Biddell Airy, a late 18th-century Astronomer Royal of Great Britain, who first derived the equation that describes this phenomenon.

For 10-inch scopes or larger, set your sights on Alpha (α) Comae Berenices. This pair has a mere 0.5" split between its 5th-magnitude stars, so you'll need all the atmospheric steadiness possible to split it. Boost the power past 400x, focus gently, and be patient. Wait a few minutes for that moment of super still air. If you manage this feat, turn to Jupiter — the level of detail at this resolution will astound the most jaded deep-sky observer.

It is here, near Canes Venatici's border with Ursa Major, that you'll find one of the finest galaxies in our sky, the Whirlpool Galaxy (M51, NGC 5194-5). This large, beautiful spiral can be found within a degree of Eta (η) Ursae Majoris, the star at the end of the Dipper's handle.

While you're checking out galaxies, notice that the constellations Bootes and Hercules are rising high in the east. In the northeast, the summer stars are beginning to make an appearance, with Vega leading the way. By 11 p.m., Vega's companions in the summer triangle are also visible. Altair can be found almost due east and Deneb is in the northeast.

This year's Eta (η) Aquarid meteor shower is favorable for early morning risers. The shower peaks on May 4, without hindrance from the moon. Because the moon sets early and is just past first quarter, its brilliance does not compete with the shower. The radiant, in the northern part of the constellation of Aquarius, rises an hour or two before dawn. You can expect about a dozen meteors per hour — up to 35 per hour if the radiant is high at your location.

By 3 a.m. local time, **Uranus** and **Neptune** are above the southeastern horizon. Both are visible among the faint stars of Capricornus the Sea Goat, but you will need binoculars. Also notice how low the line of the zodiacal constellations is during these early morning hours. At this time, the plane of the ecliptic forms a shallow angle with the horizon. This means the morning planets will not rise very high above the horizon before the sun rises. So you'll have to do most of your planetary observations in the glow of morning twilight.

Jupiter, the first of the bright morning planets, appears at around 4 a.m. It's followed 45 minutes later by **Venus**. The month begins with the two planets nearly 8° apart. Each day the separation between Venus and Jupiter increases, as Jupiter rises earlier and Venus rises later.

Mercury reaches its greatest elongation (27°) west of the sun on May 4, but remains very low for Northern Hemisphere observers. This small planet passes 0.8° south of 0.5-magnitude **Saturn** on May 12. For northern observers, the twosome will be tough to spot in the bright morning twilight. Look due east 45 minutes before sunrise, when Saturn and Mercury are just 3° above the eastern horizon. Use brighter Jupiter and Venus to find the pair. A line joining Jupiter and Venus points approximately to the location of Saturn and Mercury. As additional help, the angular distance between Jupiter and Venus is almost the same as the angular distance from Venus to Saturn.

By the third week of May, Venus and Saturn become the principal players in this morning drama. Venus is moving ever closer to Saturn, and by May 28 the twosome is separated by less than half a degree. Venus shines at a dazzling magnitude –3.9 while Saturn glows at a respectable magnitude 0.6. This is one of the finer conjunctions of the year, a stunning line-up of two planets that in reality are quite far apart.

As you observe these two wonders, remember that Venus is only six light-minutes from Earth. Saturn, on the other hand, is a giant seventy-seven light-minutes away. Through a telescope observers can see the pair in the same low-power field of view. The addition of the magnitude 8.3 saturnian moon Titan will be an added treat. Titan can easily be found between Venus and Saturn — provided the sky remains dark enough.

The two planets remain within a low-power (7x50) binocular field of view from May 22 to June 4. The next Venus/Saturn conjunction to be visible occurs on the morning of July 15, 2001. This date is far enough away to make this month's event worth watching.

The moon adds to the action on May 21–23. It begins by gliding beneath Jupiter on the 21st. Then it moves past Venus on the 22nd and Saturn on the 23rd. If the moon's orbit were aligned to the ecliptic, there is a good chance it would occult these planets every month. Unfortunately, its orbit is inclined 6° to Earth's, so the moon generally misses these planetary targets. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

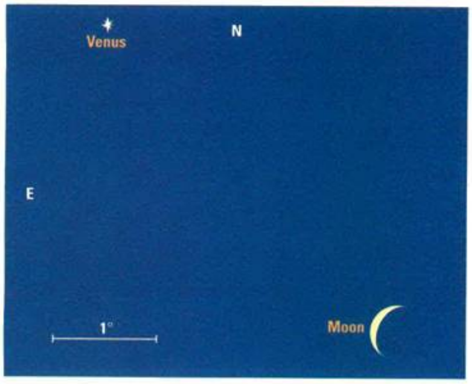
See Venus in Daylight.

Take a long lunch on Friday, May 22, and don't forget to bring your binoculars to the office. It's time to show your co-workers that astronomy can also be done during the day.

Blazing at magnitude –3.9, Venus is the easiest planet to see with the unaided eye in broad daylight. The trick is knowing where to look. On May 22, the pale crescent moon will act as your guide.

First use binoculars to see exactly where Venus is relative to the slender lunar crescent. The planet will be about 5° — one field of view in a pair of 7x50 binoculars — away from the moon and in the direction of the sun.

Don Parker



Try to place the sun behind a building or some other obstruction. Doing this will avoid the sun's glare and the subsequent tears that will blur your view. Focus your eyes first on the moon, then shift your gaze over toward Venus. Without the reference of the moon, it can be hard to see our sister planet. The human eye has trouble focusing properly on an otherwise blank sky.

As a challenge, see if you can spot Saturn in binoculars. It's located another 6° closer to the sun. If you have a telescope with setting circles, offset from Venus by 25.4' of right ascension east and 2°12' of declination north.

Lunar Limbo Dance

What phenomenon is readily visible to the naked eye but took the telescope to discover? Lunar libration.

As the moon orbits Earth, observers can occasionally see slightly more than its direct face-on view. Sometimes the moon is below the ecliptic, so northern observers look down on its north pole. At other times, the moon's fast swing at perigee carries it more than one-quarter of an orbit around while spinning one-quarter of a turn. This allows us to see some of the features normally hidden just past the limb.

On May 1, set your sights on Mare Crisium, the oval shaped sea to the moon's "upper right." This feature will be "rolled" toward us, giving a peek at what lies beyond it. By the time the moon is full, its orbital position will allow us to look at the moon from its "lower left." Mare Crisium will be tucked right up against the lunar limb.

Once you recognize this apparent back and forth rocking motion of the moon, you will wonder why you never noticed this motion before.

Bob Sandy

Lick Observatory, Univ. of California Santa Cruz

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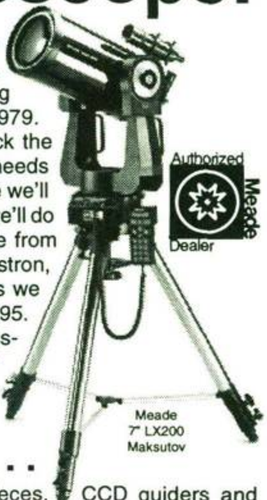
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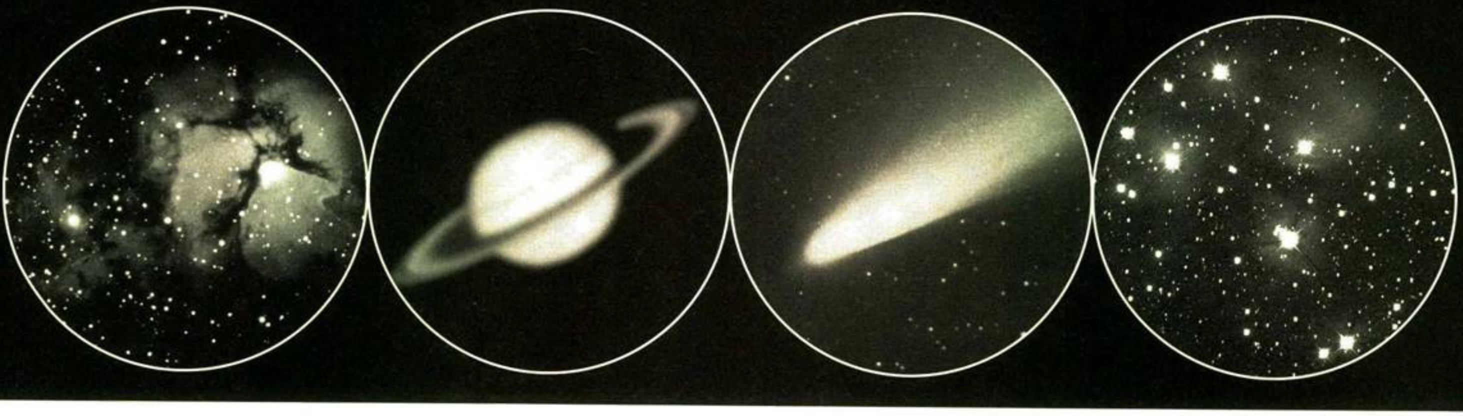

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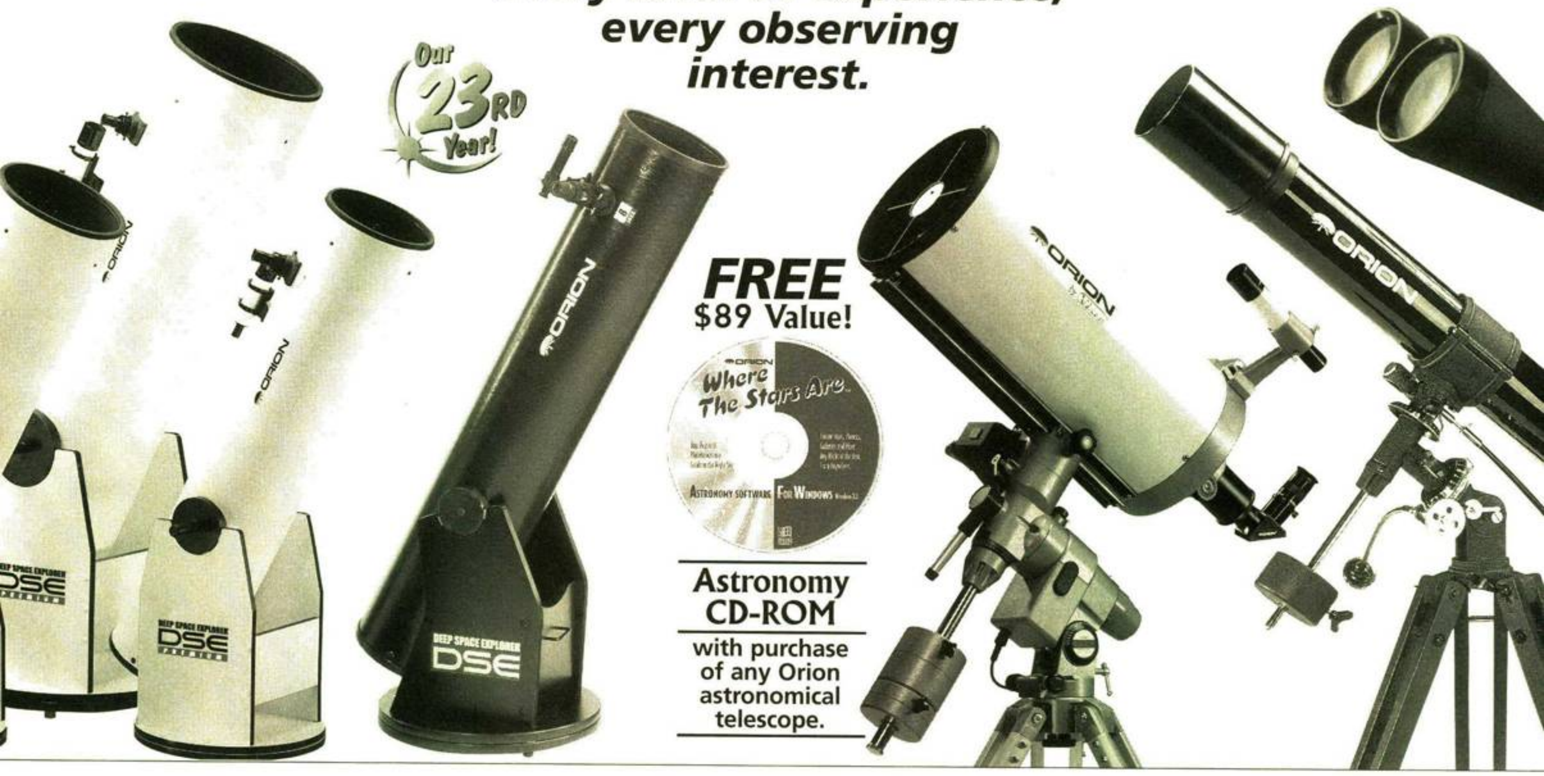
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VIRGO

If the chill of winter put you on observing hiatus, now is the time to dust off that telescope and point it skyward. A profusion of galaxies in Virgo awaits.

by Tom Polakis

THE WARM NIGHTS OF MAY offer prime conditions for galaxy hunting. The winter Milky Way is being swallowed by the glare of the sun, while the summer's star clouds in Cygnus and Sagittarius are still hours from rising. It's on these evenings that we find ourselves standing in the plane of our galaxy with nowhere to direct our gaze but outward. At the center of this view, we find the constellation Virgo.

Virgo is a sprawling prominent constellation. It's second in size to Hydra and spans more than 1294°. Its brightest star is silver-blue Spica, a spectroscopic binary with an absolute magnitude of –3.7 — that translates into a luminosity of nearly 1,740 suns.

The primary telescopic draw to Virgo is the Virgo galaxy cluster. A neighbor to our own Local Group, the Virgo cluster is the richest gathering of galaxies in the Local Supercluster — a large group of associated small galaxy clusters that include the Local Group and therefore the Milky Way.

Navigating this "Realm of the Galaxies" can seem daunting. A good approach is galaxy hopping. Simply begin with a prominent galaxy in the eyepiece and make 1° hops across the field. Knowing in advance what to expect out of your target is invaluable. Keep a photographic atlas such as John C. Vickers' *Deep Space CCD Atlas* nearby. The 4,000-plus CCD images in two volumes aid both in identification and in finding those elusive features.

Our tour through Virgo begins near the center of its dense cluster and spills northward into the neighboring constellation Coma Berenices. Two bright stars in the tail of Leo, 70 and 94 Leonis, indicate our starting point, **NGC 4216**. In an 8-inch telescope, this galaxy appears to be a very narrow streak with no sign of a central bulge, though it does exhibit a very bright central core. The similar, though fainter, **NGC 4206** rests only 12' to the southwest. Those viewing NGC 4216 with larger apertures might try to see the elongated enhancement northeast of center. This feature suggests the galaxy is a barred spiral.

A little over 2° east of NGC 4216, at the heart of the Virgo cluster, are elliptical **M84** (NGC 4374) and **M86** (NGC 4406). A very bright core dominates the

Artwork at left originally published in *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

NGC 4567 & NGC 4568

Tom Eby

M49

Dale K. Bonges

nearly circular 3' halo of M84. Even magnifying the galaxy 300x fails to show a stellar nucleus. In 1991, Japanese amateur Reiki Kushida discovered a supernova in M84. He used a 16-inch reflector and a keen eye to detect the brightened star.

At first glance, M86 appears to be a twin of M84. A closer look reveals the slightly brighter, larger, elongated, oval of M86. It has a very bright and nearly stellar nucleus, unlike the more uniform concentration seen in M84. Globular cluster data from the Hubble Space Telescope established a distance estimate of 34 million light-years. The survey of elliptical galaxies used measurements of 162 globular clusters in M86 — all fainter than 20th magnitude — as standard candles. Determining galactic distances with globular clusters is controversial and remains at the cutting edge of professional study.

M87 (NGC 4486) presents a departure from the standard elliptical galaxy. Most ellipticals are considered featureless, but it's hard to miss bright M87 1.5° east-southeast of M84. Using telescopes as large as 36 inches, Houston amateurs Barbara Wilson and Larry Mitchell have observed the galaxy's famous jet emanating from its eastern edge. At the 1995 Texas Star Party, Finnish amateur Riku Henriksson spotted it as an extension from the western edge of the core. Scopes with more down-to-earth apertures show M87 to be 3' across and perfectly round. A very bright core, one-third of the galaxy's overall size, blazes in the center. Look for two companion galaxies, **NGC 4476** and **NGC 4478**, about 10' west. The Hubble Space Telescope recently revealed a small spiral of hot gas at the center of M87. The intense gravitational field that holds this disk together is most likely the result of a massive black hole.

Continuing our sweep along the northern border of Virgo brings the scope to **M90** (NGC 4569). Small instruments show the 4' by 2' center of the galaxy. Using a 20-inch scope in Georgia, Art Russell has seen a uniform halo with a stellar nucleus that he suspects is a foreground star.

Less than 1° south of M90 is **M89** (NGC 4552), a small, round elliptical galaxy. Though it looks almost planetary-like, M89 has a pronounced nucleus and a uniform halo that fades rapidly around the edge.

Sweeping further, to slightly more than 1° south of M89, are the **Siamese Twins**, NGC 4567 and NGC 4568. Both are roughly the same size across with slightly brighter centers. The twin galaxies have been studied at several wavelengths. These studies reveal a distinct lack of detectable tidal signatures, suggesting the two are not interacting, though they appear to be joined at the ends. The distance to NGC 4678 is 55 million light-years.

A mere 0.6° to the northeast of the Siamese Twins is **M58** (NGC 4579). A 13-inch telescope in the low Arizona desert reveals a bar-shaped central feature surrounded by a diffuse halo. **M59** (NGC 4621), another of Messier's Virgo cluster ellipticals, is the most elongated on the list. It appears to be 4' by 2', with its major axis oriented

M61

Jack Newton

NGC 4569

Rudolph Schild / Harvard-Smithsonian Center for Astrophysics

M104

Jason Ware

north-south. In the same low-power field with M59 is **M60** (NGC 4649). Though it does have a bright center, this elliptical appears to be a small circular glow. Only 3' northwest of M60 is **NGC 4647**, a small , round haze easily spotted in small scopes.

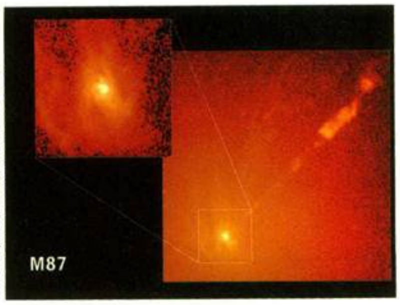
NGC 4762 is a galaxy known for its flat form. It lacks the central bulge commonly seen in edge-on galaxies, and its high surface brightness allows for wonderful, high-power views. Through an 18-inch telescope at 255x, Russell notes a stellar nucleus and estimates the size of the spindle to be 7' by 1'. An 8-inch scope shows much of this detail, although the apparent length diminishes.

Moving southward along the supergalactic plane we find **M49** (NGC 4472), one of the brightest ellipticals in the Virgo cluster. Despite its catalogued dimensions of 8.1' by 7.1', visual observers will be hard pressed to see half this size. A small scope shows a very bright nucleus which fades rapidly to a diffuse, elongated halo. A 12th-magnitude star superimposes the eastern edge of the galaxy.

To the east of M49 is the wonderful barred spiral galaxy **NGC 4535**. A 10-inch scope at a dark site shows a long bar surrounded by a mottled haze. Averted vision reveals the faint spiral arms emanating from the bar. Use the 13th-magnitude star at the north end of the galaxy as a guide to tracing one of these faint arms.

The Active Giant at Virgo's Heart

Located some 50 million light-years away at the heart of the Virgo cluster of galaxies is M87. This giant elliptical galaxy harbors a massive black hole at its center, spews out large quantities of material through its jet, and is home to some 338 possible planetary nebulae. It is a highly active region that has fascinated both amateur and professional astronomers for many decades.



M87

H. Ford (JHU/StScI), R. Harms (ARC)

Our first view inside M87 came in May 1994, when the Space Telescope Science Institute released this color photograph. The image shows a spiral-shaped disk of hot gas at the galaxy's core. Hubble's Faint Object Spectrograph measured the velocity of this material and found it orbiting at speeds of nearly 1.2 million miles per hour. This high velocity is the signature of a tremendous gravitational field. Clearly, M87 hides a massive black hole. Another possible explanation would be a large concentration of stars, but M87 contains only a small fraction of the number of stars necessary to create such a powerful attraction.

The photograph also shows M87's brilliant jet of high-speed electrons. This jet is powered by the black hole's immense gravity and density. As large as our solar system (some 3,700 million miles wide) and weighing as much as three billion suns, the black hole draws material like a gigantic galactic drain. The material swirls into the black hole's gravitational well forming a rapidly rotating accretion disk. As the material whirls towards the black hole, a jet of electrons is emitted along the axis of rotation.

Another interesting finding comes from investigations done by Robin Ciardullo and John Feldmeier from Pennsylvania State University, and George Jacoby with Kitt Peak National Observatory, NOAO. This team recently reported finding some 338 planetary nebulae in M87 and its surrounding halo. Their observations also yielded strong evidence for the presence of a "substantial population of intergalactic stars" located approximately 6.5 million light-years in front of the galaxy. The presence of these stars explains the extremely bright planetaries Jacoby encountered in a 1990 investigation of the Virgo cluster. Though not definitive, these findings suggest that the core of the Virgo Cluster is itself a dynamically young system.

—Andrea Gianopoulos

M61 (NGC 4304) is one of the largest spirals in the Virgo cluster. At its distance of 50 million light-years, the tiny angular dimension of 1" corresponds to a size of 240 light-years. That is 15 million times larger than the separation between Earth and the sun. M61 has harbored three supernovae since 1926, and its spiral arms are dominated by H II regions. This spiral structure is visible in modest telescopes, while high magnification shows a stellar core and hints of mottling in the spiral arms.

NGC 4536 is next on the docket. Small telescopes reveal an oval haze with a bright center. In a 13-inch scope, a peculiar spiral pops into view. Straight arms appear to extend away from the brighter central bar, and they show little sign of wrapping around the nucleus.

Pan 2° south and slightly west from NGC 4536 to locate **NGC 4517.** In a 13-inch scope, this galaxy appears to be a dim streak extending nearly 10' long. Its only texture is a faint core and a 10th-magnitude star just northeast of the nucleus. Also look for its companion, **NGC 4517A,** to the north.

The bright star 15° northwest of Spica is the beautiful binary star Porrima (Gamma [γ] Virginis). The term "headlights" has been coined to describe doubles like Gamma Virginis. Such pairs have nearly equal magnitude and give the appearance of an oncoming vehicle. Not only do the components of Gamma Virginis appear equal, their intrinsic luminosities,

Goddess of the Harvest

Virgo

"Virgin august! come in thy regal state
With soft majestic grace and brow serene;
Though the fierce Lion's reign is overpast
The summer's heat is all thine own as yet,
And all untouched thy robe of living green
By the rude fingers of the northern blast."
— R. J. Philbrick

Philbrick's words illustrate Virgo's association to the Greek goddess Demeter (Ceres to the Romans), the corn goddess, goddess of the fields and harvest. It is a constellation that comes to the forefront during the months of spring — a time when we sow our crops and Earth awakens from its winter sleep. Her celestial portrait paints this same association. She is most often illustrated as a feathery winged maiden holding an ear of wheat, marked by the star Spica in her left hand and the quill of some long feathered bird in her right.

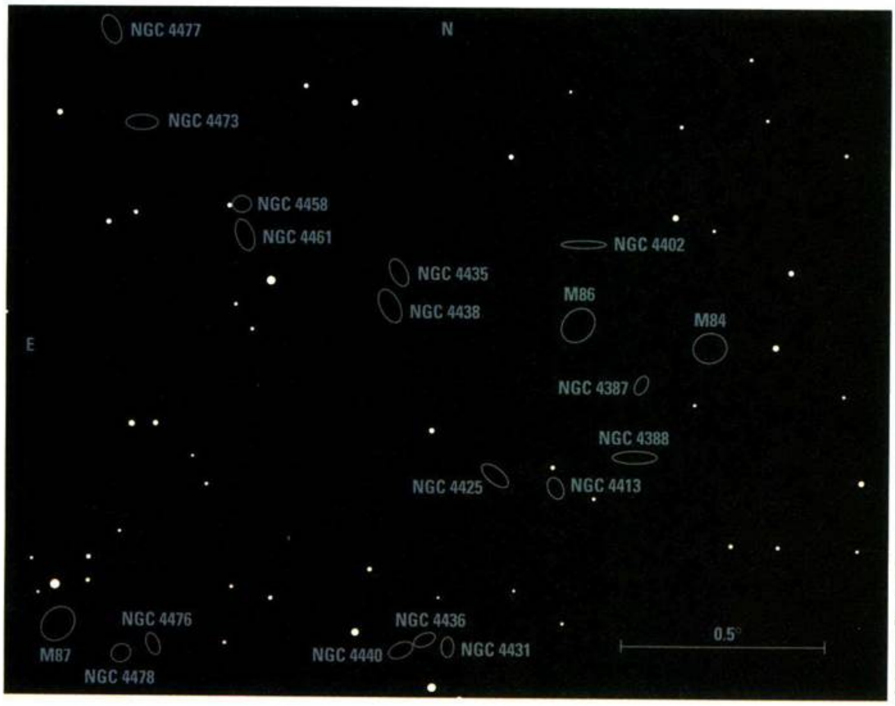
Virgo is one of three female constellations depicted in their entirety — the mother and daughter team of Cassiopeia and Andromeda are the other two. Virgo is also connected with the Greek goddess Dike, daughter to Zeus and Themis. She is the goddess of wisdom and justice. It's no coincidence that the constellation of Libra the Scales or Balance rests at Virgo's feet.

According to the myth, Dike lived during the Golden Age of humankind, a time when her grandfather (Kronos) ruled from Mount Olympus. It was a time of peace, happiness, and perennial spring. Humans knew nothing of war, sorrow, or work. But her father (Zeus) overthrew Kronos, ushering in the Silver Age. This was a time when men quarreled over money and refused to honor the gods. Disenchanted and longing for days gone by, Dike tried to convince mortals to return to the ideals of their ancestors. Unfortunately, they ignored her. This fatal error ushered in the Bronze Age, a time when men were violent warriors. Ultimately, Dike became disgusted with the world. She abandoned humankind and flew to heaven where she sits today, harboring those wondrous galaxies and offering us the promise of days gone by.

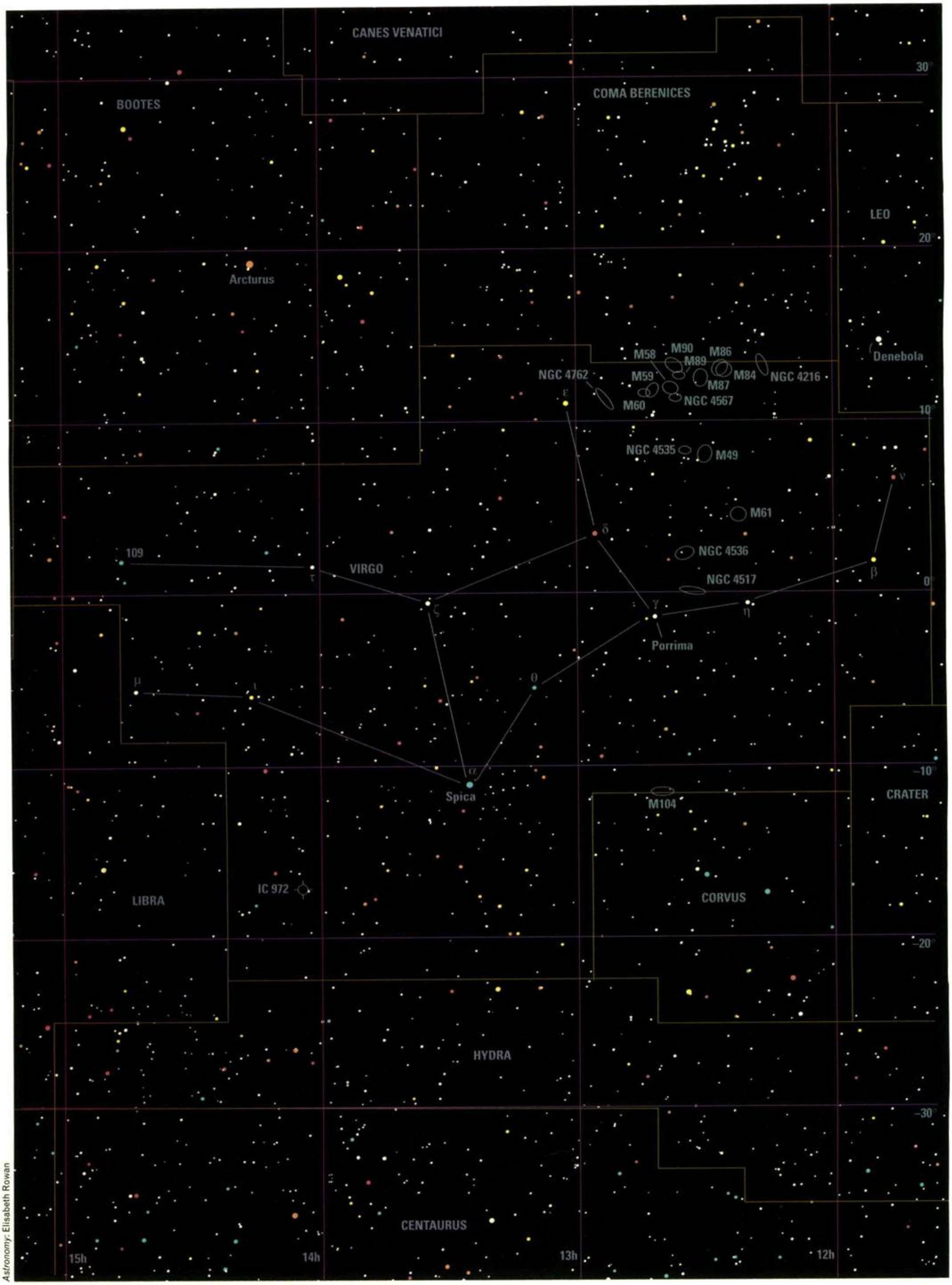
— A.G.

Virgo cluster

Jason Ware



Astronomy: Elisabeth Rowan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14h
13h
12h

Astronomy: Elisabeth Rowan

M87

Jack Newton

NGC 4535

Jack Newton

M84 & M86

Jerry Lodriguss

temperatures, and masses are very similar as well. The two have magnitudes of 3.5 and are currently separated by 2", so a good set of optics can easily split them. During the next decade, the pair's orbital motion will bring the separation down to less than 0.5".

The **Sombrero Galaxy** (M104, NGC 4594) is always a favorite. Its lenticular form and bisecting dust lane are easily seen in small scopes. Because the Sombrero is inclined 6° to our line of sight, its dust lane appears to cross just south of center. In smaller aperture scopes, this lane is only visible near the bright middle. A large halo surrounds the core, though it tapers with distance along the galaxy's major axis. M104 has as many as 2,000 globular clusters — contrast that to the Milky Way's 160 and the Andromeda Galaxy's 350.

Our last stop is a planetary nebula in a lonely corner of Virgo. **IC 972** is the 37th entry in George Abell's compilation of 86 suspected planetary nebulae. Appearing as gray discs on the Palomar Observatory Sky Survey plates of the 1950s, Abell planetaries are large and notoriously faint. Abell 37 is one of the few planetaries in the catalog that is visible without a nebula filter in a 10-inch — though you increase your chances of seeing it with the filter. In a 13-inch scope, it appears uniform and moderately bright with a sharply defined edge.

Tom Polakis is an aerospace engineer living in Tempe, Arizona. His primary astronomical interests are deep-sky observation and photography.

Deep-Sky Objects in Virgo

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
NGC 4216	12h15.9m	13°09'	10	7.8' x 1.6'	Gal	SAB(s)b
M61 (NGC 4303)	12h21.9m	04°28'	9.7	6.0' x 5.9'	Gal	SAB(rs)bc
M84 (NGC 4374)	12h25.1m	12°53'	9.1	5.1' x 4.1'	Gal	E1
M86 (NGC 4406)	12h26.2m	12°57'	8.9	12.0' x 9.3'	Gal	E3
M49 (NGC 4472)	12h29.8m	08°00'	8.4	8.1' x 7.1'	Gal	E2
M87 (NGC 4486)	12h30.8m	12°24'	8.6	7.1' x 7.1'	Gal	E0
NGC 4517	12h32.8m	00°07'	10.4	9.9' x 1.4'	Gal	Scd
NGC 4535	12h34.3m	08°12'	10	7.0' x 6.4'	Gal	SAB(s)c
NGC 4536	12h34.5m	02°11'	10.6	6.4' x 2.6'	Gal	SAB(rs)bc
M89 (NGC 4552)	12h35.7m	12°33'	9.8	3.4' x 3.4'	Gal	E
NGC 4567	12h36.5m	11°15'	11.3	2.7' x 2.3'	Gal	SA(rs)bc
M90 (NGC 4569)	12h36.8m	13°10'	9.5	10.5' x 4.4'	Gal	SAB(rs)ab
M58 (NGC 4579)	12h37.7m	11°49'	9.7	5.5' x 4.6'	Gal	SAB(rs)b
M104 (NGC 4594)	12h40.0m	–11°37'	8	7.1' x 4.4'	Gal	SA
Gamma Vir	12h41.7m	–01°27'	3.5,3.5	1.8"	Dbl	-
M59 (NGC 4621)	12h42.0m	11°39'	9.6	4.6' x 3.6'	Gal	E5
M60 (NGC 4649)	12h43.7m	11°33'	8.8	7.1' x 6.1'	Gal	E2
NGC 4762	12h52.9m	11°14'	10.3	9.1' x 2.2'	Gal	SB(r)0
IC 972 (Abell 37)	14h04.4m	–17°15 '	13.9	43"	PN	-

Object: Designation in Messier, NGC, or other catalog. **R.A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./ Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Hubble type for galaxies or type for variable stars.

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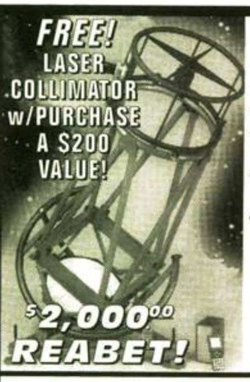

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ask Astro

A found meteorite, the speed of gravity, supersonic jets

Q: I think I found a meteorite. Where can I send it to authenticate that what I have is indeed a meteorite? — *Dave Ayala, Fullerton, California*

A: Meteorites often look different from the rocks that surround them. They often look black because of the presence of a fusion crust, the result of surface melting caused by friction as they plunge through our atmosphere. The flight through the atmosphere may also cause bowl-shaped depressions or thumbprinting (regmagyphts) of the surface. And, because almost all meteorites contain iron, they feel heavy for their size and will attract a magnet.

So if you find a black, heavy rock that looks different than surrounding rocks, perhaps with a thumbprinted surface, and attracts a magnet, you may have discovered a meteorite! If you think you have, visit your nearest museum that has meteorites on display, or send it or a portion of it (at least several grams) to:

The Institute of Meteoritics, Department of Geology, University of New Mexico, Albuquerque, NM 87131; or Lunar and Planetary Laboratory, Space Sciences Building, University of Arizona, Tucson, AZ 85721. — *Jim Phillips*

The heat of atmospheric entry formed the dark fusion crust of this carbonaceous chondrite meteorite. Jim Phillips

Q: Can you please explain right ascension and declination? — *Gary Kahler, Silver Spring, Maryland; Clifford Liongue, Melbourne, Australia; and Kevin Weisbender, St. George, Kansas*

A: Right ascension and declination are the sky's version of the longitude and latitude coordinate system we use on Earth. To specify a geographical location on Earth, say, where I'm located here in Sault Ste. Marie, Michigan, you'd write its latitude as 46 degrees, 30 minutes north, and its longitude as 84 degrees, 23 minutes. A similar system is used to plot positions in the sky.

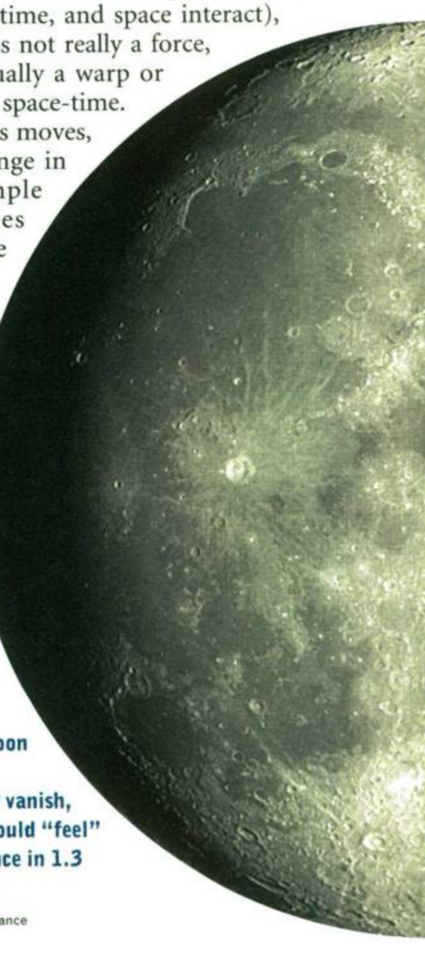
The declination scale is merely Earth's latitude projected into space, so a star directly overhead in my backyard would be at 46 degrees, 30 minutes. Because the sky appears to rotate (360 degrees in 24 hours, or 15 degrees in one hour as Earth spins), you can't simply project your longitude into space. So astronomers developed a different measure for celestial longitude, one they call right ascension.

Along the celestial equator, where the declination is 0 degrees, one hour of right ascension covers 15 degrees of sky. Using this system of measurement, in 24 hours the sky naturally divides itself into 24 fifteen-degree increments, each of which is called one hour of right ascension. The starting point for this right ascension scale, called 0 hours, is where the sun crosses the celestial equator each spring. Lines of right ascension run perpendicular to circles of declination, just as lines of longitude run at right angles to the parallel lines of latitude on Earth. — *John Shibley*

Q: What is the speed of gravity? If the moon were to suddenly disappear, how long would it take for us to feel the impact on the tides? — *Frank Hanou, Silver Spring, Maryland; Nathaniel Grant, Melbourne, Australia; and Rick Adams, Eagle River, Alaska*

A: This question confuses a lot of people, and for good reason: The answer is difficult to relay without resorting to some pretty hairy physics. However, there is a quick answer: Gravity propagates at the speed of light.

According to Einstein's general theory of relativity (which basically is a mathematical description of how matter, time, and space interact), gravity is not really a force, but actually a warp or bend in space-time. If a mass moves, the change in the dimple it makes in space



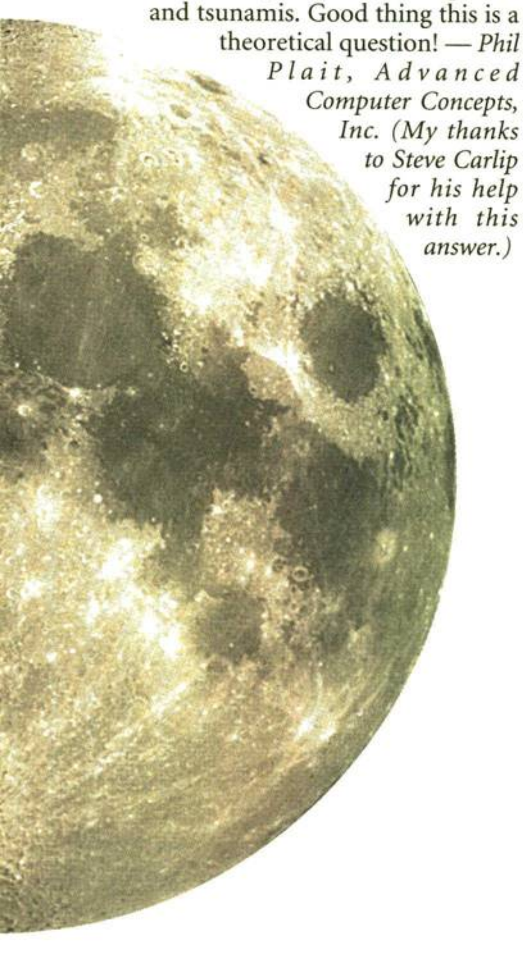
If the moon were to suddenly vanish, Earth would "feel" its absence in 1.3 seconds.

Gregory Terrance

actually propagates outward at the speed of light.

The tidal force on Earth from the moon is due to the fact that gravity gets weaker with distance. The side of Earth nearer to the moon gets pulled stronger than the far side, so Earth feels a stretch, making the planet somewhat prolate (football-shaped). The effect is not huge, but it is substantial: The solid crust beneath our feet rises and falls about 12 inches (30 cm) a day due to the tidal stretching.

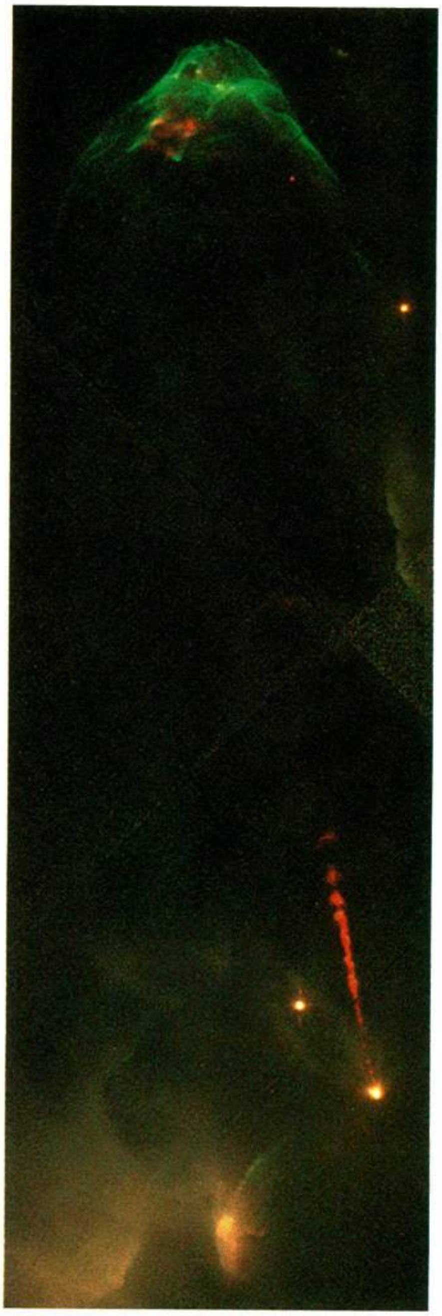
If the moon were to suddenly vaporize, the dimple in space the moon makes would suddenly snap flat. This effect would travel outward at the speed of light, reaching the near side of Earth in just over a second. It would propagate through Earth, reaching the far side about 0.04 seconds later. Earth itself would feel a relief (ever taken your belt off after a big dinner?) and would try to reset itself into a more spherical shape. That effect would move through Earth at the speed of sound and might cause earthquakes and tsunamis. Good thing this is a theoretical question! — *Phil Plait, Advanced Computer Concepts, Inc. (My thanks to Steve Carlip for his help with this answer.)*



Q: One periodically comes across references to the word "supersonic" in articles about astronomy. A typical reference would be a jet of hot gas shooting away from a star or galactic nucleus. Is there an astronomy-specific meaning to the word, or does "supersonic" speed suggest that the jet only exceeds the velocity of sound waves in Earth's atmosphere? — *Mark Lancaster, Baltimore, Maryland*

A: The term supersonic means the same thing in astrophysics as it does in terrestrial physics. It's true that interstellar gases are incredibly rarified, with as little as one atom per cubic inch or less (a billion trillion times lower than the density of air at Earth's surface). But the timescales and sizes involved in these clouds are so long (thousands of years) and so large (trillions of miles) that these atoms do manage to find each other in collisions. The more collisions that occur, the more the particles act like a gas. That means they do have a temperature and a pressure and therefore a speed of sound.

So a jet emitted by a young star is supersonic if as a whole the gas is traveling faster than the speed of sound in the gas that comprises the jet. The sound speed is a basic reference because sound is the way a gas passes information around about internal changes. For example, imagine a jet pushing into a cloud at a speed higher than the speed of sound in the cloud. Sound waves move ahead of the jet into the cloud material to let it know what's coming. But since the jet is moving faster than the speed of sound, it arrives before the sound waves, and thus becomes a "gas-dynamic surprise" to the cloud. This is the process that creates shock waves. — *Adam Frank, University of Rochester*



A supersonic jet from a young star slams into the surrounding interstellar gas, causing the gas to light up and glow as a green shock region at the top. Jeff Hester (Arizona State University), et al., and NASA

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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$99.95

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	$99.95
Giant Rich-Field Viewer (10-14'')	$250.00

Optional Eyepiece	TRUE FIELD	Price
Meade 32mm Plossl	1.4°	add $99
Meade 32mm 2'' Wide-Field†	1.9°	add $429
Meade 40mm 2'' Wide-Field†	2.4°	add $489

†Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

PENTAX 65° XL EYEPIECES

AMAZING performance! **All have** 20mm eye relief, adjustable helical eye guard, super multicoatings, **E.D. glass**.

5.2mm F.L., 65° A.F. 1¼''	$279
7mm F.L., 65° A.F. 1¼''	$279
10.5mm F.L., 65° A.F. 1¼''	$269
14mm F.L., 65° A.F. 1¼''	$269
21mm F.L., 65° A.F. 1¼''	$269
28mm F.L., 55° A.F. 1¼''	$259
40mm F.L., 65° A.F. 2''	$299

MEADE 7'' - 16'' LX200

NEW! 7'' - 10'' LX50

16'' LX200 $14,950

8'' LX50
$1395

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller.
LX200 - full computer control w/64K obj. mem.
Tripod: extra for LX50; included for LX200
NOTE: A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200.

NEW! 3.5'' f/14 ETX Maksutov ($20)	$595
ETX, showroom price *(no 8 month wait)*	$695
8'' LX10 w/wedge, hand controller ($65)	$995
Field Tripod for 8'' LX10 ($20)	$195
8'' LX50 w/wedge ($105 P&S)	$1395
Adj. tripod for 8-10'' SCT ($30 P&S)	$295
8'' LX200 w/computer ($105 P&S)	$2795
Wedge for photographing w/8'' LX200	$139
7'' LX50 f/15 Maksutov w/wedge ($125 P&S)	$1795
10'' LX50, f/10 w/wedge, dec. motor, hand controller ($145 P&S)	$1695
10'' LX200 w/computer ($145 P&S)	$3195
12'' LX200 (f/10 only)($215 P&S)	$4495
Super Wedge for photogr. w/10'',12'' LX200	$395
16'' LX200 f/10 w/tripod ($385 P&S)	$14,950

Dew Shields: 8'' .... $119; 10'' $129
12'' .... $189; 16'' $289

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4''—8'', f/6 or f/10	$249
Giant EASY-GUIDER for 10''/12'' f/4-f/10	$395

MEADE STARFINDERS

8'' f/6
$749

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6'' f/8 Dobsonian Starfinder ($46 P&S)	$319
6'' f/8 Equat. Starfinder 6(add $79 P&S)	$649
8'' f/6 Dobsonian Starfinder (add $59 P&S)	$419
8'' f/6 Equat. Starfinder 8 (add $89 P&S)	$749
10'' f/4.5 Dobsonian Starfinder ($85 P&S)	$599
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	$879
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	$895
16'' f/4.5 Dobsonian Starfinder (freight COD)	$1195
16'' f/4.5 Starfinder 16 (ship. freight COD)	$2695

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

Magellan computer; specify Dob. or Eq. ($15 ship)	$295
LUMICON 1¼'' UHC or O-III Filter	$99.50

Vinyl covers to keep dust-free (2 req.) for 6'' - **$10**; for 8'' - **$15**; for 10'' - **$20**; for 16'' - **$35**

SKY VECTOR™ $299!!

Includes Computer, Encoders, Hardware

LOW PRICE—from $299

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $299

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349

Over 3600 objects! — Also includes planets and full visual descriptions.

NGC SKY VECTOR™ $439

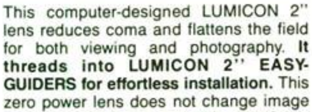
12,000 Objects!— PC Serial Port

NGC-Sky Vector™
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON®

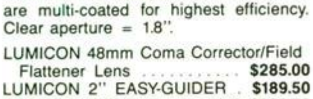
NGC SKY VECTOR with IDENTIFY (Sky Tour) mode, 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16'' Dobsonian.
Ultima 8, 9¼, 11 **add $25**, C-14 **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½'' f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	$285.00
LUMICON 2'' EASY-GUIDER	$189.50
2'' EASY-GUIDER (Mamiya 645)	$239.50
2'' Adapter for Pentax 6X7	$129.00
2'' Adapter for Hasselblad	$229.00
2'' Adapter for Bronica SQ-A	$175.00
2'' Extension for viewing	$26.00

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	$259.00

LUMICON ACCESSORIES

LUMICON, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	$119.50
UV/Dust Deal for Celestron C-8	$39.00
UV/Dust Seal for Meade 4''—8''	$39.00
UV/Dust Seal (lg.) for Meade 10''—12''	$89.50
UV/Dust Seal for Celestron-11, -14	$89.50

LOW PROFILE FOCUSERS

New! Thread-on for Odyssey

FROM $69.50

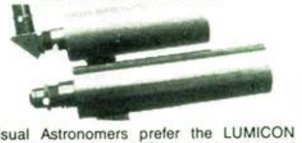
LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape!
Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	$69.50
LUMICON 2'' Helical Focuser 1½'' high	$75.00
LUMICON Non-rotating Helical Focuser	$129.00
2'' Astro Systems focuser, only 2'' high	$139.00
3 handles for non-rotating focuser	$12.95
2''/1¼'' adapter w/48mm filter threads	$20.00
2'' LUMICON EASY-GUIDER	$189.50

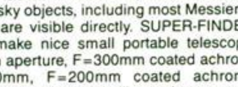
LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope $69.50, 45° version	$69.50
1¼'' straight-thru 80mm SUPER-FINDER	$199.50
1¼'' right-angle 80mm SUPER-FINDER	$209.50
1¼'' right-angle version, w/star diagonal	$239.50
25mm Cross-hair 1¼'' eyepiece (12X)	$59.00
Large mounting rings for 80mm Finder	$55.00
1¼'' Star Diagonal $49, Mounting Brackets,	$39.50
1¼'' 45° diagonal for correct left-right views	$59.50

PROTECTIVE DUST COVERS



Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser	4/$2		
2'' O.D. plug	2/$2	3½'' O.D. plug	$1.50
1¼'', 1⅜''	3/$2	7½''	$10
1½''	2/$2	9½'', 10.4''*	$15
2''	2/$2	12½'', 12⅞''*	$20
2⅛''	2/$20	15.0'', 15.6'', 16''*	$28
5½''	$6	19'' (DS-16)	$35
*Fits Odyssey		21'' (Odyssey-II)	$35

Meade & Celestron
LUMICON carries a full line of telescopes and accessories. Fast Delivery, Competitive Prices.

LUMICON FOR HIGH PERFORMANCE

Visit our LUMICON web-site: http://Astronomy-Mall.com/Lumicon

NEW LUMICON MULTIPLE FILTER SELECTOR

ALWAYS GET THE BEST VIEW!

$99
(If ordered with LUMICON filter or filter set)

The New LUMICON Multiple Filter Selector holds up to 5 1¼" LUMICON filters. The sliding bar has a click-stop at each filter position. Now you can instantly select the best filter for any deep-sky object. Cost is $129 or $185 with 1.5X relay lens (for Newtonians). **Save $30 if ordered with filter(s)!**

TELE VUE™

NEW! Bino Vue Binocular Viewer

Genesis-SDF 4" f/5.4 apochromat	**$2125**
Pronto 70mm f/6.4 apochromat w/2" diagonal	**$969**
Pronto 70mm f/6.4 w/45° erecting prism	**$839**
NEW! Bino Vue binocular viewer	**$899**
Gibraltar mount with ash wood tripod	**$535**
10.4, 26mm Plossl 50°	**$79**
8, 11, 15mm Plossl . **$95**, 20, 25mm	**$105**
32mm Plossl, widest true field in 1¼"	**$125**
55mm 2" Plossl, widest possible field	**$235**
2.0x or 3.0x Tele Vue Barlow Lens	**$119**
2" Giant Barlow - 2x	**$185**
4.8mm Nagler, 82° field, 1¼" eyepiece	**$175**
7mm Nagler, 1¼" eyepiece, 82° field	**$225**
9mm Nagler, 82° field, 1¼" or 2"	**$245**
13mm Nagler, 82° field, 1¼" or 2"	**$315**
12mm Nagler, Type II, 82°, 1¼"/2"	**$295**
16mm Nagler, Type II, 82°, 1¼"/2"	**$315**
20mm Nagler, Type II, 82°, 2" only	**$395**
2" Paracorr Visual Coma Corrector	**$259**
15mm Panoptic 1¼", 68° field	**$215**
19mm Panoptic 1¼", 68° field	**$245**
22mm Panoptic 1¼"/2", 68°	**$285**
27mm Panoptic 2", 68° field	**$335**
35mm Panoptic 2", 68° field	**$365**

TeleVue Warranty may not be valid outside USA.

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
2.14"	**$59.50**	2.60"	**$75.00**	3.10"	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$189.50**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain."
***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

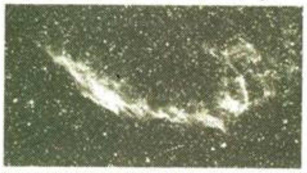
"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

BETTER THAN A DARK-SKY SITE!?

"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$79.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$199.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$199.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	**$399.50**
2" Rear Cell Filter, fits SCT's ... Deep-Sky, **$199.50** UHC, O-III, H-Beta,	**$199.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Choice of ***any two*** LUMICON filters (**Save 7%**) ... 1¼" **$185.00**; 48mm	**$370.00**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** ... **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼" $99.50; 48mm**	**$199.50**
LUMICON Comet (Swan band) Filter ... **1¼" $99.50; 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$7.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$19.50**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$25.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) Filter.

Specify Lens Size	**H-Alpha**	**(DS)**
46, 48, 49mm	**$59.00**	**$199.50**
52, 55, 58, 62mm	**$69.00**	**$199.50**
67, 72, 77mm	**$79.00**	**$399.50**
82mm (77mm + adapter)	**$89.00**	**$415.00**

Hypered 2415 film, 36 exp .. **$11.95, $3/$32**

LUMICON®

2111 Research Dr. #5A, Livermore, CA 94550
For phone orders please call (925) 447-9570
FAX (6 PM-9 AM PST) (925) 447-9589
LUMICON Products catalogue FREE
All foreign orders add 8% ($10 minimum)
California residents add 8.25% tax.
Prices subject to change w/o notice.
Hrs M-F 9 am - 5 pm. Sat. 9 am - 1 pm

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

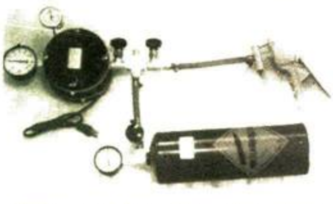
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$109.50**

Guider for Hasselblad **$489**, Mamiya 645 **$259**
Pentax 6X7 **add $129**; Pentax 645 **add $149**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$299**, Mamiya 645 **$98**
Pentax 6X7 **add $129**; Pentax 645 **add $149**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) .... **add $179.50**
Adapter for Hasselblad **$399**, Mamiya 645**$149**
Pentax 6X7 **add $139**; Pentax 645 **add $159**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** ..... **$119.50** Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.
2. **Cable release** for long exposures . **$9.95**
3. **Declination motor** (state telescope type) **$109**
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left) .
6. **LUMICON 48mm DEEP-SKY FILTER $199.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

TRY PPF! HYPERSENSITIZED FILM

SR1600
Scotch
1000
TP 135-36

HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
Kodak PPF-400, THE BEST!	36	**$14.95**
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Gold 1000 fast, fine grain	12	**$13.95**
Fuji G800 fine grain color neg.	24	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

The Little SCOPE that Could

Remember the Volkswagen Beetle? If you were a bona fide bell-bottom-wearing child of the 60s and 70s, you probably owned and drove a "bug." The most popular car of its day, the VW Beetle was compact, easy to handle, and very affordable. And who could deny the uniqueness of that beetle-shaped chassis, usually painted fire engine red? The Beetle was ideal in two roles — as a first car for the budget-minded new driver and as a second car for families seeking a sporty backup vehicle. The Volkswagen Beetle — the "little car that could" — was and still is a classic.

Astronomy's answer to the VW Beetle is Edmund Scientific's Astroscan 2001 — a 4¼-inch f/4 "rich-field telescope." Like the automobile, the Astroscan is compact, easy to handle, and very affordable. It, too, sports a unique design (best described as a stubby tube jutting out of a bowling ball). The Astroscan's color? Red, of course. And like the VW Beetle, the Astroscan is popular with beginner and expert alike. The Astroscan 2001, now in its third decade of production, is a classic in its own right.

Like the VW Beetle, the Astroscan has remained largely unchanged over the years. The one I acquired back in 1979 is virtually the same scope being produced today — with one major exception. The original Astroscan had no finder. It was assumed that the 3° field generated by the Astroscan's standard 28mm RKE eyepiece would be adequate for locating sky objects. It wasn't. Because of the Astroscan's unique shape, I couldn't sight down the tube at a sky object. The first night out, I actually had trouble finding the Pleiades. Apparently, other Astroscan owners had similar problems. A removable finder sight now comes standard with each Astroscan. With it, targeting sky objects is easy. Warning to hat wearers: As you peer into the eyepiece of an Astroscan, the

Astronomy: Rebecca Saliture

The Astroscan 2001 will long be a classic among beginners and experts.

by Glenn F. Chaple, Jr.

visor of your baseball cap will bump into the finder, knocking the scope off target. Solution: Remove your hat or wear it backwards.

The Astroscan is a bantam among telescopes. Just 17 inches long and weighing 8.5 pounds, it easily fits into a gym bag. A lightweight, three-pronged dish serves as the mount. The "bowling ball" portion of the main scope fits snugly into the dish, allowing motion in any direction. Aim the Astroscan toward the zenith, and the eyepiece is a mere 14.5 inches above the ground. If you're over two feet tall, you'll need to place scope and mount on a stable, elevated surface. I've enjoyed many hours sitting at a picnic table with my Astroscan exploring the wonders of the night sky. If you feel more comfortable with a traditional tripod, Edmund Scientific offers an optional bracket that lets you mount the Astroscan on a standard camera tripod. (Edmund Scientific also supplies a folding tripod for the Astroscan.) Want to make your own Astroscan mount? Directions for constructing a solid, inexpensive tripod from standard PVC plumber's supplies appear in the September 1991 issue of *Astronomy*, page 84.

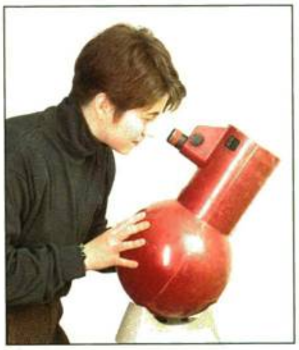
For the novice, the Astroscan has few equals. It's lightweight and easy to handle. The primary mirror is permanently mounted into the tube, while the secondary is fixed to a clear optical plate at the front of the tube. This closed system reduces the need for the occasional collimation and mirror cleaning that often makes reflecting telescopes unpopular with beginners. The tube, fashioned out of high-impact plastic, is extremely durable. I wasn't about to test my Astroscan by willfully tossing it onto a brick sidewalk, though I had heard accounts of Astroscans being dropped and surviving unscathed. As it turns out, I inadvertedly did the "drop test" anyway. Out one night for a series of observations on an eclipsing variable star, I accidentally knocked the scope from its mount and watched in horror as it bounced across the lawn. The damage done? The eyepiece fell out and the finderscope required a little readjustment when I got it back on its mount. Otherwise, none. During mosquito season, be careful applying bug spray which, if accidentally sprayed onto the Astroscan, can create a dull, tacky area on the tube.

Two things may deter the beginner from purchasing an Astroscan. Unfamiliar with the high cost of quality astronomical equipment, he or she might be put off by the Astroscan's price of more than $300. But, unlike the cheap telescopes found in most department stores, the Astroscan is a solid performer designed to last a lifetime. At a time when some eyepieces retail for over $200, the Astroscan is a true bargain. Another potential turn off is the Astroscan's low magnifying power — just 16x with the 28mm RKE eyepiece provided. I give Edmund Scientific Company credit for not falling sway to high-power mania. The Astroscan is, after all, a "rich-field" telescope. As such, its purpose is to provide a spectacular wide-field low-power view. The beginner needs to know that 16x is adequate magnification for a wide variety of sky sights — from craters on the moon to galaxies millions of light-years away. Want higher magnification for planetary detail and

Courtesy of Volkswagon of America

small-scale deep-sky objects like double stars and planetary nebulae? Purchase an 8mm RKE or similar focal length eyepiece and you have 56x, which can be doubled with a good Barlow lens.

What possible use would the experienced amateur astronomer, already in possession of a 17.5-inch Dobsonian-mounted reflector or similar large telescope, have for an Astroscan? Plenty, if he or she travels or vacations frequently. An Astroscan fits in with the luggage much better than a 17.5-inch Dob. Secondly, veteran skygazers know that no single telescope can do it all. Because it's a rich-field telescope, the Astroscan is tailor-made for viewing large deep-space objects and star fields. Sure, I struggled a bit to find the Pleiades on that first night out (no problem now that I have a finder). But once the Pleiades slipped into view, I was mesmerized. For the first time ever, I saw this cluster the way it was meant to be seen. Not small, as seen with my 7x50 binoculars, or chopped up by the limited field of a large telescope, but large and intact — and spectacular. The best small-scope view I ever got of the Andromeda Galaxy was with an Astroscan. The wide 3° field nicely framed this great spiral and its companion galaxies. My only telescopic sighting of the elusive North America Nebula was with an Astroscan (a finder chart and clear, dark skies helped).



As you gain observing experience, you can "push" your Astroscan to do some big-league work. All it requires is the use of eyepieces with shorter focal lengths to increase magnification and contrast. The Astroscan works well with a variety of 1.25-inch eyepieces. A 9mm Nagler gave a particularly impressive view, with crisp star images across a wide field. (I had to support the Astroscan with a free hand, because the weight of this huge eyepiece kept tipping the little scope over.) Using a 12mm König eyepiece, I could glimpse the Veil Nebula, traditionally a big-scope target (again, a finder chart helped). With the standard 28mm RKE in place, the Astroscan showed the globular star cluster M13 in typical small-scope style — a fuzzy ball of light. Switching to a 5mm Orthoscopic eyepiece and using averted vision, I could actually resolve this great stellar swarm. What impresses me most about the Astroscan is its ability to maintain a quality image, even when rigged with a high-power eyepiece like a 4mm or 5mm Orthoscopic.

Variable star observers take note: The Astroscan, with its wide field, is the perfect tool for studying bright variable stars. The 3° field of the 28mm RKE lets you work comfortably with variables in the magnitude-6 to 10 range. A 6mm to 8mm eyepiece will still cover a field over half a degree across, while revealing stars as faint as 12th magnitude. With my Astroscan, I've done some "serious" work on eclipsing variables, obtaining useful data in the process.

The best testimony of a telescope's success comes from the comments you get at a gathering of amateur astronomers. At the Stellafane Convention last summer, I set up an Astroscan near my campsite. Several Astroscan owners converged on the site, each lavishing praise on the capabilities of this little scope. No doubt about it, for beginner and expert alike the Astroscan 2001 is the "little telescope that could."

Chaple, a teacher living in Townsend, Massachusetts, is a frequent contributor to Astronomy *and* Odyssey *magazines. He is also coauthor of the* Edmund Mag. 6 Star Atlas.

STANDARD SPECIFICATIONS

Clear aperture: 4.125 inches (105mm)
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Focal ratio: f/4.2
Length of tube: 17 inches
Size of focuser: 1.25 inches
Included 1.25-inch eyepiece:
28mm (RKE, 16x, 3.0° field)
Finder: Open sight target finder
Secondary size (minor axis): 1.5 inches
Secondary obstruction (by diameter): 36%
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Total telescope weight: 10.4 lbs (4.7 kg)
Weight of heaviest component (tube): 8.4 lbs (3.8 kg)
Eyepiece height at zenith: 14.5 inches
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Manufacturer direct price: $329, plus $18.55 shipping and handling

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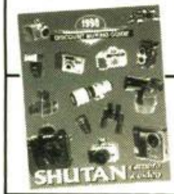

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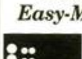
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Easy Guide

Invent your own constellations and learn the night sky in a matter of minutes.

by Bob Berman

You love astronomy. A few stars and constellations are already familiar. You're ready for the next step — the leap to deeper sky knowledge. You'd prefer if it were quick and painless. You've come to the right place.

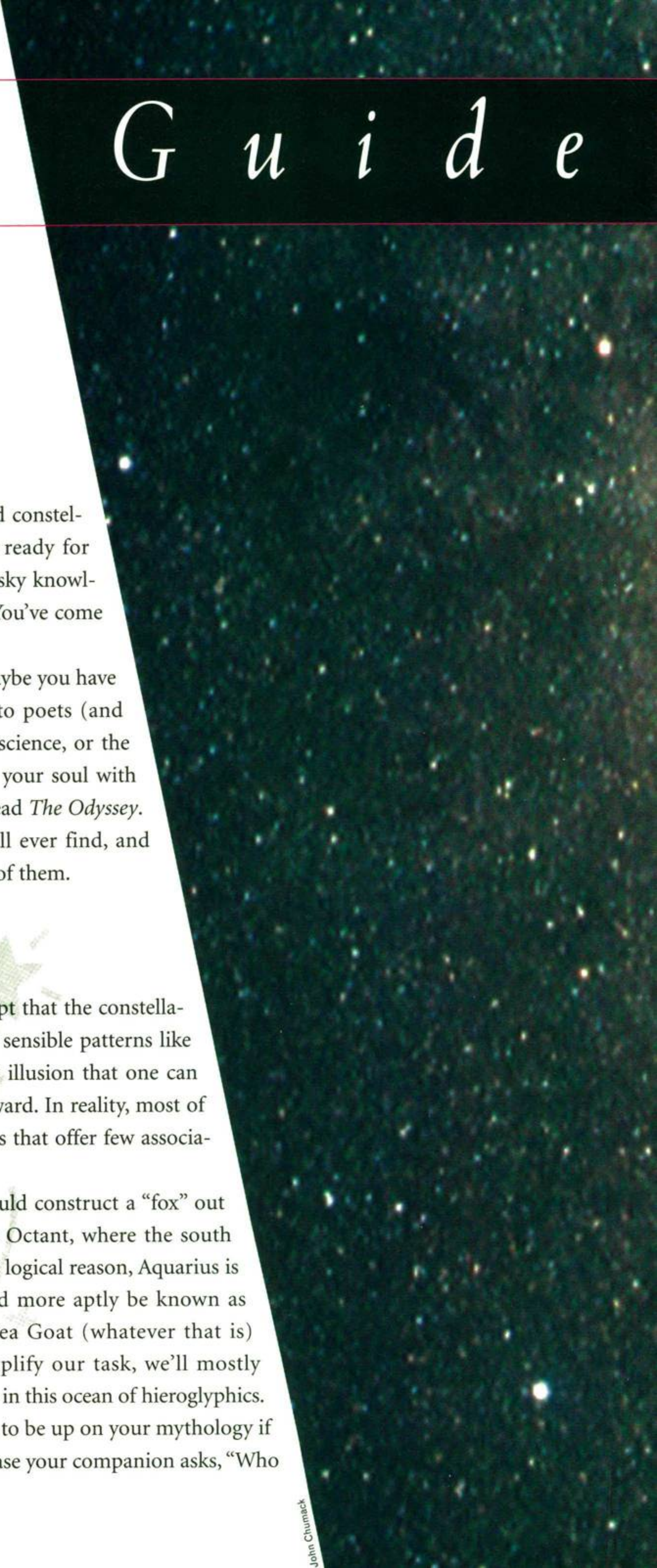
Noble or base, your motive doesn't matter. Maybe you have an inherent love of the night that bonds you to poets (and criminals) throughout the ages. Maybe it's the science, or the infinitude. Or maybe you feel you ought to fill your soul with classical pursuits, but hate opera and refuse to read *The Odyssey*. The sky's constellations are as classical as you'll ever find, and they're easy and fun to learn — there are just 88 of them.

Forget the Greeks

First, a vital starter tip: From the get-go, accept that the constellations are a confusing mess. The tiny handful of sensible patterns like Orion and Scorpius are only teasers, giving the illusion that one can actually see mythological figures by looking upward. In reality, most of the sky is crowded with faint Rorschach patterns that offer few associative possibilities.

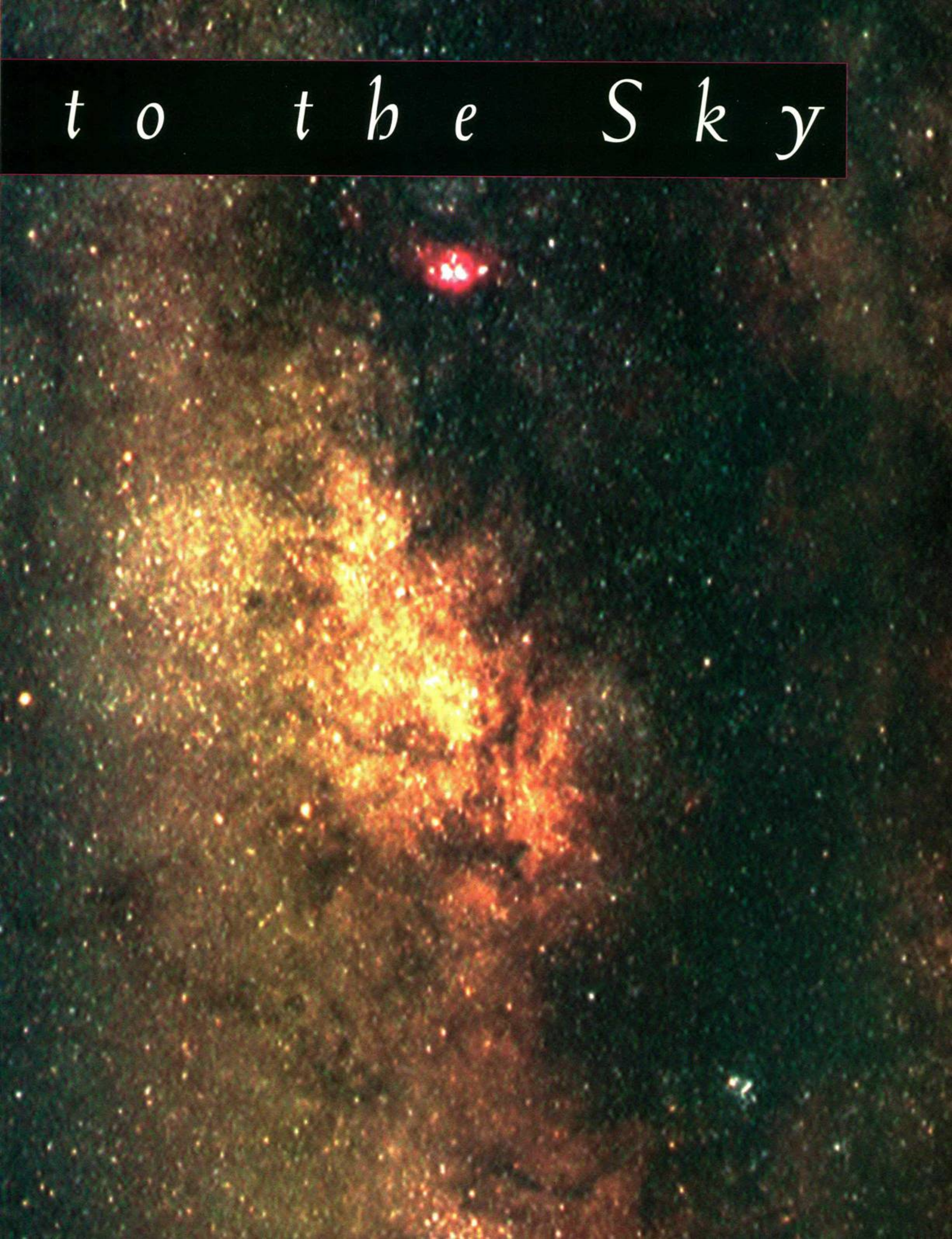
Without use of illegal substances, nobody could construct a "fox" out of the dim suns of Vulpecula. And Octans the Octant, where the south celestial pole sits, is so faint it's not there. For no logical reason, Aquarius is labeled "man with a water jug" when it should more aptly be known as "medley of random dots." Capricornus the Sea Goat (whatever that is) boasts the outline of New York State. To simplify our task, we'll mostly identify the sensible patterns, the islands of sanity in this ocean of hieroglyphics.

Once you've learned a constellation, you have to be up on your mythology if you're to come up with a reasonable answer in case your companion asks, "Who



John Chumack

to the Sky



is that guy? What's a Centaur?" For example, rising in the southeast late in the evening is a string of faint stars called Ophiuchus, "The Serpent Bearer," as if there ever really were such a profession. Well, maybe a long time ago. But no employment agency has found work for a serpent bearer for approximately 2,160 years. Reptile porters, let's face it, have gone the way of oxcart drivers and Macintosh programmers.

Those of us living in the Northern Hemisphere at least see constellations named chiefly in classical times. Although most have alien names and confusing configurations, they've at least been screen-tested by dozens of human generations.

When you travel near the equator or into the Southern Hemisphere, however, you're really on your own. There, the stars were named by 16th- and 17th-century sailors drifting beneath unfamiliar skies. Unversed in the classics, impulsive, and totally unconcerned about matching their imaginary objects with actual star patterns, they simply named parcels of celestial real estate after whatever new birds and animals they came across and the instruments that got them there. That's why we're saddled with essentially vacant pieces of night bearing designations such as Tucana the Toucan and Sextans the Sextant.

But we're stuck with them. Linking these faint stars into patterns is no solution. Switching to yet more Greek mythology to match the northern sky would mean unearthing esoteric legends that make even less sense than the famous ones, where gods routinely meted out bizarre punishments (like chaining beautiful women to rocks) for minor offenses that should have been thrown out of traffic court.

You also have to allow that constellations, when they resemble anything at all, look entirely different from what their names suggest. Cassiopeia doesn't resemble a "lady on a chair" but rather the letter M or W, depending on the season or time of night. Virgo doesn't look like a virgin (I'm not going to touch that one) but instead appears to be the letter Y. Sagittarius so resembles a teapot that mapmakers have essentially given up trying to force an Archer out of this pattern; on most modern charts it is labeled a teapot. It's no longer hip to pretend to find a Big Bear in the stars of Ursa Major. It's a Dipper. Or, if you live in England, a Plow.

So let's first set up a list of realistic items to "see" in place of the bizarre, obscure, classical patterns:

OLD CONSTELLATIONS	ACTUAL OBJECTS
Virgo (Virgin)	Letter Y
Cassiopeia (Lady in Chair)	Letter M
Sagittarius (Archer)	Teapot
Capricornus (Sea Goat)	New York State
Auriga (Charioteer)	Pentagon
Taurus (Bull)	Letter V
Cepheus (King)	Another pentagon
Aries (Ram)	Three stars, period
Canes Venatici (Hunting Dogs)	Two stars
Delphinus (Dolphin)	Kite
Coma Berenices (a Queen's Hair)	Buckshot

There are many others, but the best strategy is simply to form your own shapes and learn them that way. That's allowed. The only no-no: You can't join stars of two or more adjacent constellations. You have to keep the official boundaries. Those are the rules.

Okay, we're ready to start. My "infallible method" of star learning, which works most of the time, involves learning just three simple sky regions and then branching out from there. Three large ones are plenty, because as the sky rotates you're sure to have two in view at any time of night and any season. Recognizing two swaths of the heavens at all times is ample and those familiar regions will serve as splendid jumping off points to more obscure constellations, with an atlas.

Zone One: The Spring Sky

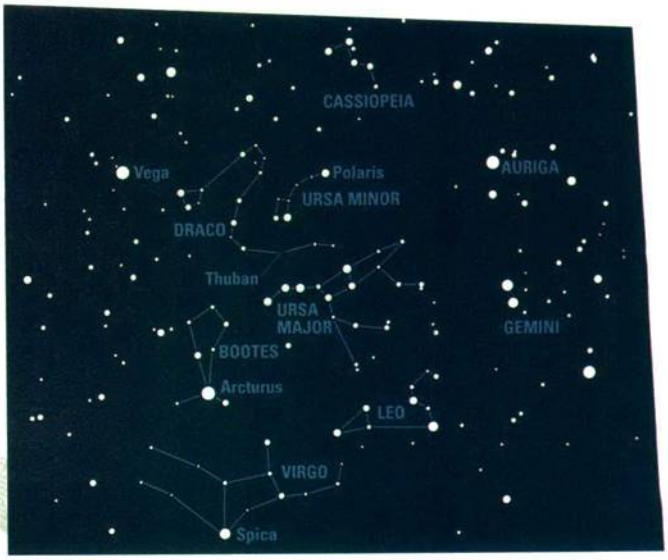
Zone One is found halfway up the northern sky, and it's always visible to Northern Hemisphere viewers. It's the one you can turn to when all else fails because it's the only one that barely shifts position.

You start with the Big Dipper. You know you can handle this; it's always in the north — high up in the spring and low in the fall. (My personal mnemonic: fall low and spring high.) Follow the two end stars of the Dipper's bowl to point downward (in the spring) or upward (in the fall) to Polaris, the north star. Polaris is at the end of the Little Dipper's handle, a curved string of faint stars you'll find easily once you've escaped city light pollution. Try Greenland.

In spring, you can follow those leftmost Big Dipper "pointer" stars the wrong way, upward, to Leo the Lion; it goes nowhere else. Next, look at the one medium-faint star between the Big Dipper's handle and the Little Dipper's bowl, and you've found Thuban, which was directly over the North Pole 5,000 years ago. It's the alpha star of Draco the Dragon. That skimpy string of faint stars weaving between the Dippers and ending up between the Little Dipper and Vega (which we'll learn in a minute) is all Dragonstuff.

When the Big Dipper's high, look low in the north for the W of Cassiopeia. In fall they switch roles and it's the Dipper that's low and Cassiopeia (now an M) that's high.

Through spring and summer, follow the arc of the Big Dipper's handle to the brilliant orange star Arcturus (in other words, you follow "the arc to Arcturus") in the abstract constellation Bootes, supposedly a "herdsman" but actually more like a messy underwear drawer. You can also follow that huge arc further to the only low, southerly, bright star, the blue Spica (follow the spike to Spica), the main star of



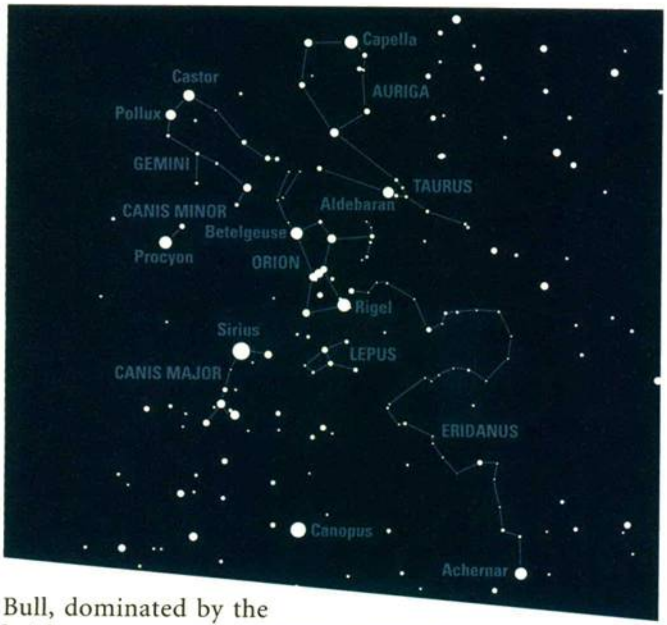
Virgo. And boom: Suddenly you've got seven constellations. What did that take? Two minutes?

Zone Two: Orion's Neighborhood

In winter and early spring, the three stars of Orion's belt are unmistakable. Using the bright stars above and below the belt, it's easy to envision a Hunter (or an environmentalist, a serial killer, any human figure whatsoever). Follow the belt down to the left to dazzling Sirius, the Dog Star, and you've found Canis Major. This was considered an "unlucky" grouping for centuries, despite the Kennel Club's objections.

To Orion's upper left float two stars of almost equal brightness — the Gemini twins. They must be fraternal because Pollux is a bit brighter than Castor and slightly orange. Halfway between Pollux and Sirius sits the brilliant Procyon, which, when linked with the only nearby star, produces Canis Minor, the small dog. Imagine: Two stars, and you're supposed to see a dog. Better make it a chihuahua.

Due north of Orion is winter's highest bright star, the yellowish Capella, in the pentagon-shaped constellation Auriga. Then follow Orion's belt rightward to the "V" of Taurus the Bull, dominated by the bright orange star Aldebaran. Next, the line of stars extending rightward from Orion's bright bluish "foot" star, Rigel, is the snake-like constellation Eridanus the River. Finally, everything you see below Orion is Lepus the Hare. A bunny? Sure. After two or three shots of tequila. Presto: Eight more constellations!

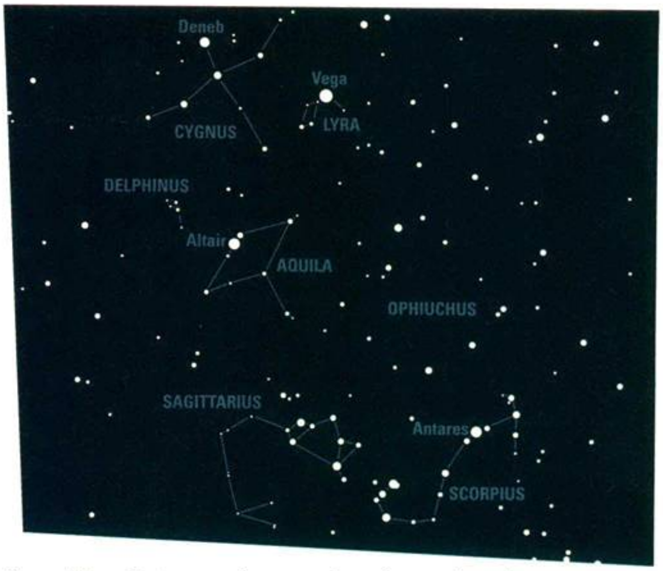


All maps: *Astronomy*: Terri Field

Zone Three: Summer Stars

Next we turn to the summertime, which can be more confusing because the Milky Way tumbles across the sky, spilling a myriad of faint stars like fireflies. Look almost straight up at midnight in mid-June, or 10 p.m. in mid-July, or nightfall in mid-August, and there's the famous, brilliant, blue-white star Vega (where the aliens' radio signal originated in *Contact*).

Vega lies amid a quintet of little stars that comprise Lyra the Harp. Four of these form a perfect parallelogram; envision strings between them and you're seeing the sky's only musical instrument. (You get a ten-point bonus if you can imagine the harp's lilting chords; Lyra's actual accompaniment is usually the drone of mosquitoes.) This overhead group makes a good focus for summer exploring, especially from a lawn chair or blanket. The next brightest star, southeast of Vega, is Altair of Aquila the Eagle. Keep going a bit further in that direction to the little kite-like quintet of Delphinus the Dolphin. Summer and fall's final bright high-up star (though a bit dimmer than Vega or Altair) is Deneb, the tail of Cygnus the Swan, east of Vega.



Next, look south from Vega to the only bright orange-red star of the warm season; you've found the heart of Scorpius, the great Antares, never high up from our latitude. The Scorpion is probably the most realistic of all the constellations, but from the northern half of the United States its tail scrapes along the horizon like a vacuum cleaner. Left of Scorpius is the teapot of Sagittarius, home to the center of the Milky Way. The "steam" pouring out of the spout is the very location of our galaxy's heart. Boom: Six more constellations.

The Top 20

There you have it. The top 20. Together they embrace every bright (first-magnitude) star seen from most of North America and Asia and all of Europe except for autumn's solitary Fomalhaut, low in the south. Math majors or other sticklers for detail might point out that we've just enumerated 21 rather than 20 constellations; this kind of pickiness is incompatible with visualizing abstract patterns.

There are just a few other rather dim formations that nonetheless are easy to find, like spring's Corona Borealis (a semi-circle) or fall's Pegasus (a square). With just a little effort you've captured all of these for keeps — the sky's elite — the constellations worthy of sharing, the ones that manage to look like something despite the ancients' best efforts at leaving us a legacy of lunacy. ■

Bob Berman is Director of the Overlook and Storm King Observatories in upstate New York. The paperback version of his book Secrets of the Night Sky *was published in 1996 by HarperCollins.*

STAR STUFF

PRODUCTS

AdaptIII CCD Camera

▶ New from PixelVision, *AdaptIII* is a high-frame-rate, low-noise CCD camera for adaptive optics imaging. Designed for high-performance imaging at rates up to 10,000 frames per second (fps), *AdaptIII* features a back-illuminated CCD and generates its high frame rates through the use of multiple outputs and proprietary amplifier designs. At 250 fps, noise performance is as low as three electrons rms and at 1,250 fps, fewer than 12 electrons rms — performance made possible by 40 output amplifiers that are digitized, multiplexed, and sent over a serial fiber-optic transmission link to a PixelVision LynxPCI interface board.

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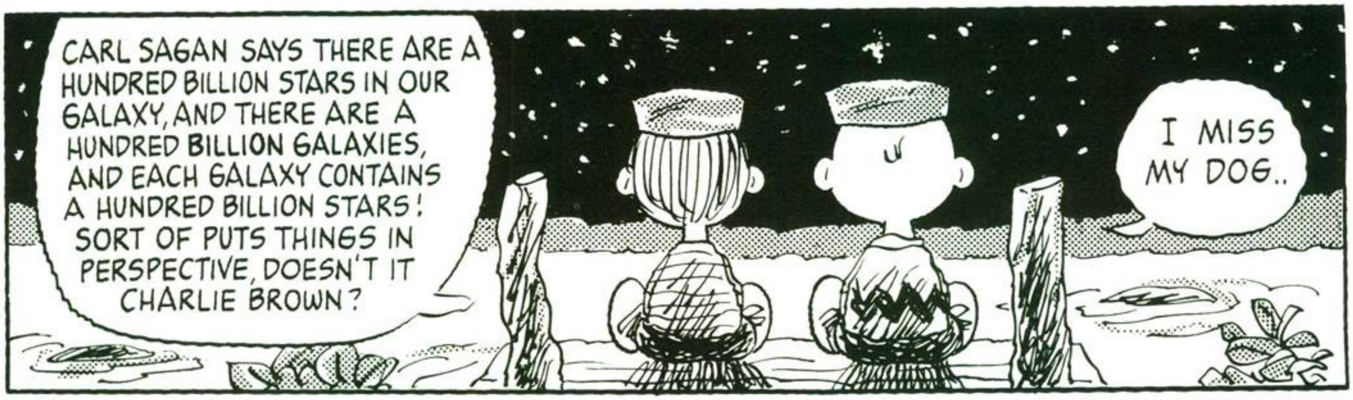
PixelVision, Inc., 14964 NW Greenbriar Parkway, Beaverton, OR 97006; phone, (503) 629-3210; fax, (503) 629-3211; website, http://www.pv-inc.com. *AdaptIII*: $98,000.

Omega Speedmaster Collection

▶ In celebration of Speedmaster's 40th anniversary, Omega is offering collectors and brand enthusiasts a unique watch collection — commemorating the highlights of space exploration. Part of the standard EVA (Extra Vehicular Activity) equipment of all astronauts and cosmonauts for their walks in space, Speedmaster watches were created in 1957 and "flight-qualified for all manned space missions" in 1965. Speedmaster watches have made six moon landings — among them Neil Armstrong's first-ever walk on the moon.

Omega has created a special series of 22 Speedmaster watches, each with a different official mission patch on its dial at 9 o'clock, ranging from the August 1965 Gemini V mission to the November 1973 Skylab SL-4. Also included in the collection is a replica of the original 1957 Speedmaster with black-mat dial, applied Omega logo, luminous hands, and arrow-tipped hour hand. The 23 watches are presented in a valise covered with genuine spacesuit cloth, which will take on its own color with time.

Omega, Bienne, Switzerland; phone, 41 32 343 98 67; fax, 41 32 343 94 97; website, http://www.omega.ch; e-mail, watch@omega.ch. *Omega Speedmaster Collection*: $65,000; individual watches (available in 1999): $2,495 each.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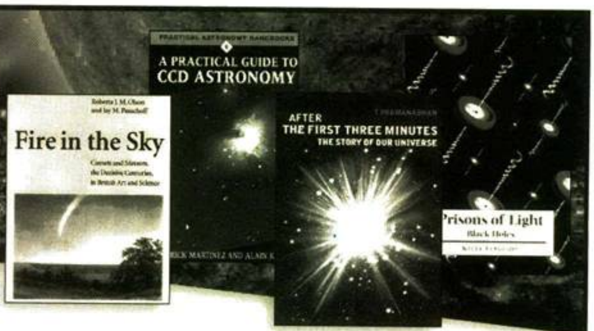
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Milton D. Heifetz *and* ***Wil Tirion***

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– Science Books & Films

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Practical Astronomy Handbooks 8

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▶ *ScopePACK,* a specialized backpack designed to carry a camera with a mounted telephoto lens up to 80mm or a spotting scope on its tripod, was recently acquired by the Saunders Group from its original manufacturer and enhanced and updated to match the rest of the OutPack Photo Backpacks product line. One of its greatest advantages is that it lets observers carry spotting scopes without removing them from their tripods. Once packed, *ScopePACK*'s padded adjustable harness and waist belt features and its variable-height sternum strap support weight securely, evenly, and comfortably.

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Saunders Group, 21 Jet View Drive, Rochester, NY 14624; phone, (716) 328-7800; fax, (716) 328-5078; e-mail, saunders7@aol.com. *ScopePACK:* $139.95.

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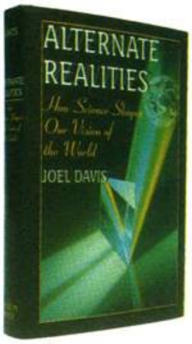
Sky Valley Scopes, 9215 Mero Road, Snohomish, WA 98290; phone, (360) 794-7757; e-mail, svscopes@jetcity.com. *8-inch diameter*: $175; *10-inch diameter*: $210; *12-inch diameter*: $250.

BOOKS

Alternate Realities

Joel Davis, 309 pages, Plenum Press, New York, 1997; ISBN 0-306-45629-X, hardcover, $27.95.

▶ Our knowledge of science is always growing, and as a result, our sense of the world and of reality is forever being altered. The more we learn, the more our vision of the world and the universe changes. In *Alternate Realities* science writer Joel Davis seeks to help his readers understand that scientific discoveries have not only contributed to advances, but have shaped and transformed concepts of reality itself. Davis examines reality as it has been perceived over the last several centuries and focuses on the characters and developments that have been most influential in shifting that reality. From Galileo and Newton to Hubble and Wheeler, those who have dared to push humanity to think differently and to challenge our concept of the universe take center stage in this book. Additionally, Davis, praised as a great popularizer of science, takes some of the most complex and yet crucial discoveries made in the past several hundred years and breaks them down into clear, lucid explanations — from the big bang theory to Schrödinger's cat to the uncertainty principle. At once scientific, historical, and philosophical, *Alternate Realities* forces its readers to recognize the limitless effects that discovery has had and will continue to have on humanity. — *Jeanette Brown*

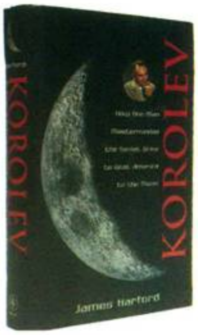


Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon

James Harford, 392 pages, John Wiley and Sons, New York, 1997; ISBN 0-471-14853-9, hardcover, $30.

▶ From imprisionment in a Soviet gulag on illegitimate charges to the leader of his nation's space program . . . how did Sergei Pavlovich Korolev do it? He was a mysterious figure, essentially unknown even in his own country, but he was also the mastermind behind the launch of Sputnik, Yuri Gagarin's historic space flight, the launch of the first intercontinental ballistic missile, and the Soviet attempt to beat America to the moon.

Korolev, a book by James Harford based on interviews with the engineers and scientists who worked alongside the mastermind as well as with family and friends, delves into the mystery and intrigue that span four decades, from the 1930s to the 1960s, of Korolev's remarkable rise against a repressive regime and his incredible ability to



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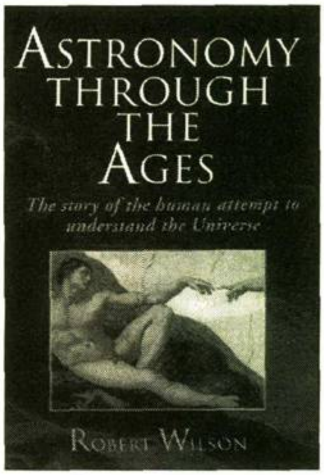

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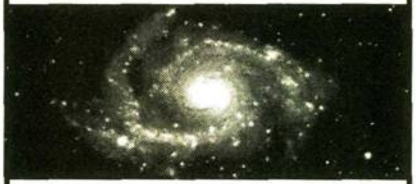

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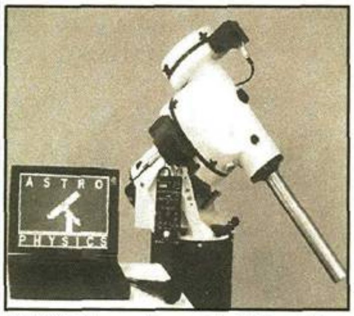

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Stars of the First People

Dorcas S. Miller, 346 pages, Pruett Publishing Co., Boulder, Colorado, 1997; ISBN 0-87108-858-4, softcover, $19.95.

▶ *Stars of the First People* is a extensive compilation of the fruits of many years of research by Dorcas S. Miller into the field of Native American star mythology. Miller uses a wonderful talent for storytelling to convey to her readers the fascinating Native American belief systems about the stars — rich, complex stories about the constellations that are separate from the traditional Greek constellations and myths. The vast amount of written material, organized by location and tribe, is complemented by more than 75 illustrations and star charts. Miller pays close attention to the cultures that give rise to the assorted myths and stories, quite a feat when one considers that for many constellations, each of several tribes in different North American locations have their own individual stories. She has received wide-spread praise from other reviewers for successfully and concisely presenting an exhaustive and previously unparalleled study of Native American astronomy. — *J. B.*

A BYTES

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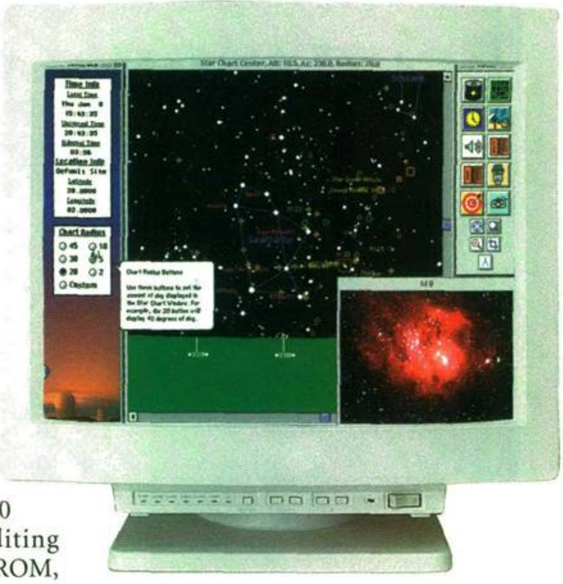
Magellan Systems Corporation, 960 Overland Court, San Dimas, CA 91773; phone, (909) 394-5000; fax, (909) 394-7050; website, http://www.magellangps.com. Price: $99.99; cigarette lighter adapter: $14.99. Minimum requirements: Windows 3.1, Windows 95, or Windows NT.

Observer for Macintosh

▶ Created with the amateur astronomer in mind, *Observer for the Macintosh* is a quality planetarium sky simulation program that provides useful tools for observing sessions. Use it for everything from planning sessions to observing in the field — including for astrophotography and CCD imaging efforts.

Observer is available in three versions: Observer Basic (featuring 9,000 stars and 3,000 deep-sky objects), Observer 68K (featuring 260,000 stars and 40,000 deep-sky objects), and Observer Advanced (featuring 475,000 stars and 125,000 deep-sky objects). Ths Star Chart window is the software package's centerpiece and provides the ability to create highly configurable star charts that can be personalized by design. Charts can be printed in portrait or landscape mode and chart graphics can be exported to PICT files. In addition to these features, *Observer* is also designed to speak to you. Implementing Apple's PlainTalk speech generation software, *Observer* puts deep-sky object information into words — you need only click on the object that interests you. A last optional addition is the ScopeLink Telescope Interface System, which allows *Observer* to guide automatically to any object in its vast database, letting observers spend more time viewing and less time searching for objects.



Procyon Systems, 1322 Augusta National Boulevard, Winter Springs, FL 32708; phone, (407) 366-5985; website, http://www.procyon-sys.com; e-mail, observer@procyon-sys.com. Price: Observer Basic, $49.95; Observer 68K, $79.95; Observer Advanced, $149.95; Observer 68K/ScopeLink Bundle, $299.95; Observer Advanced/ScopeLink Bundle, $349.95. Minimum requirements: Power Macintosh or PowerPC PowerBook with Color QuickDraw, System 7.0 or higher, Apple Speech Extension, Speech Control Panel. **A**

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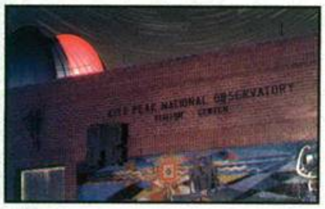

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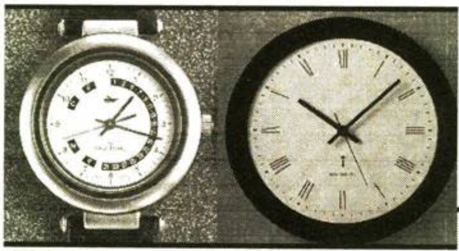

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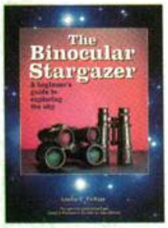

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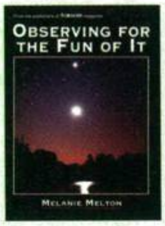

Makes viewing the night sky with tips and techniques that help the reader find and identify stars, planets, and moons; watch meteor showers and eclipses; and learn how to buy and use binoculars and telescopes. 7⅜ x 9¼; 104 pgs.; 24 illus.; softcover.

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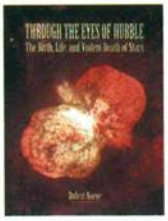
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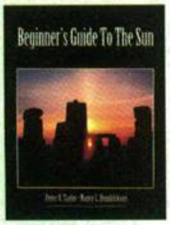

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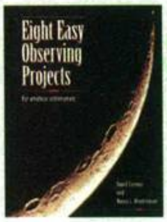

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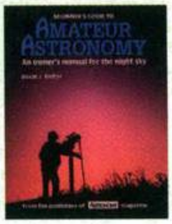

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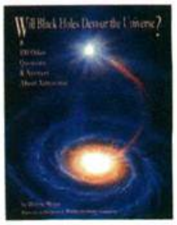

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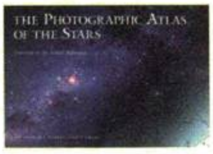

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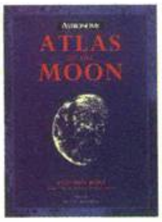

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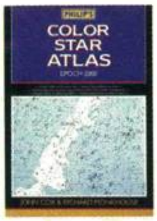

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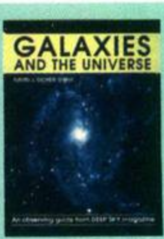

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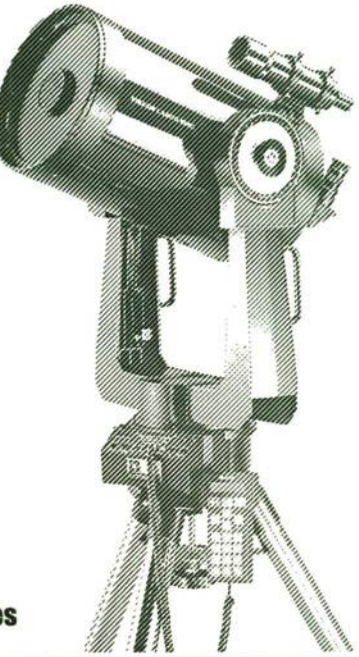

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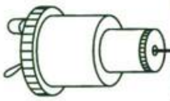

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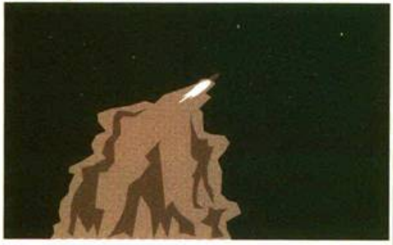

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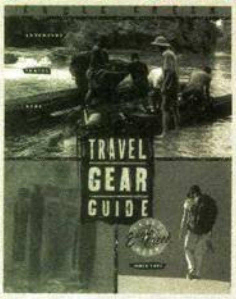

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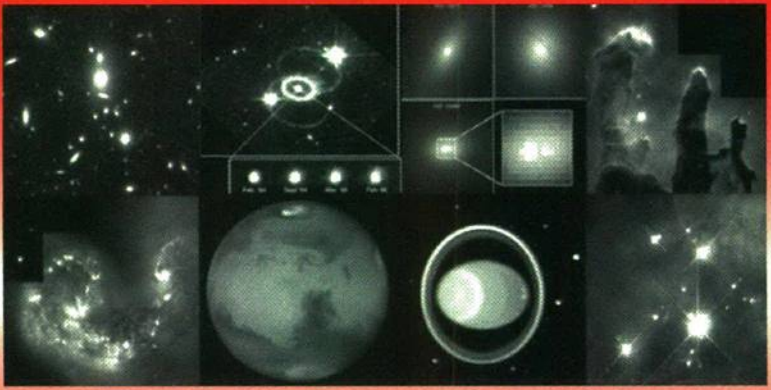

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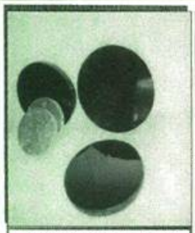

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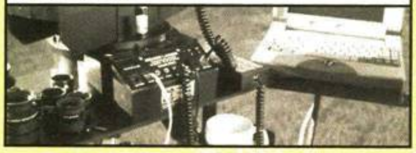

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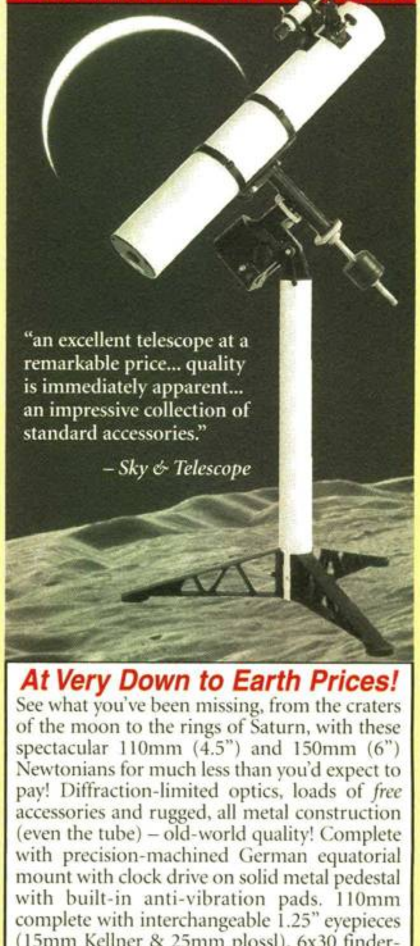

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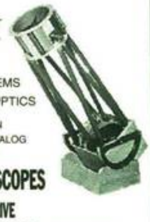

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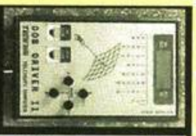

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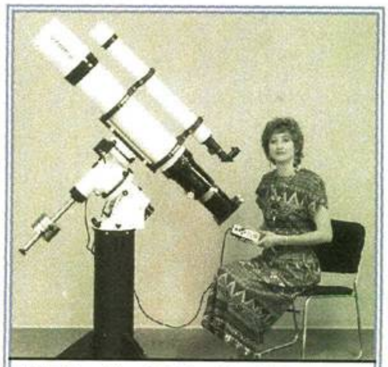

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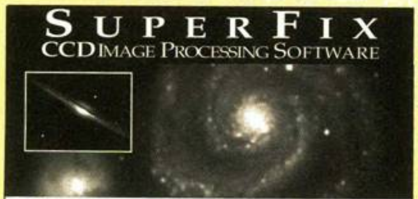

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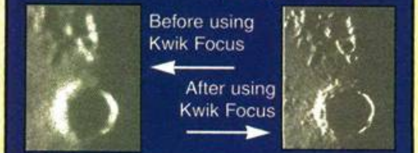

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Space Day, May 21, a day dedicated to the extraordinary achievements, benefits, and opportunities in the exploration and use of space, brings space education online with its website, http://www.spaceday.com. This site offers a comprehensive resource of space information which helps visitors plan events, holds creative classroom activities for teachers to download, and on May 21, a **Cyber Web Cast** on the internet will provide a live interview program with guests whose vision, talent, and dedication have helped us reach for the stars and beyond.

Join us next month for ***Astronomy's* 25th Anniversary Star Party, June 25**, at Rio Rancho Balloon Fiesta Park near Albuquerque, New Mexico, from 1 p.m. to midnight. Meet *Astronomy*'s editors, see the finest in astrophotography and space art, and help us celebrate 25 years of publishing. For more information, write to *Astronomy*'s 25th Anniversary Star Party, c/o *Astronomy*, P.O. Box 1612, Waukesha, WI 53187-1612; or see our website, http://www.astronomy.com.

APRIL 27–MAY 1

Astronomy Week

▶ Adler Planetarium, 1300 South Lake Shore Drive, Chicago, Illinois. Contact (312) 322-0304; 24-Hour Information Line, (312) 922-STAR; website, http://astro.uchicago.edu/adler/.

MAY – WEEKENDS

Planetarium Star Shows

▶ Hudson River Museum of Westchester, Andrus Planetarium, 511 Warburton Avenue, Yonkers, New York. For more information, call the 24-Hour Hotline, (914) 963-2139.

MAY 2

Astronomy Day

▶ Boston Museum of Science, Science Park, Boston, Massachusetts. For information, send a SASE to Noreen Grice, Charles Hayden Planetarium, Boston Museum of Science, Boston, MA 02114; (617) 589-0273; e-mail, grice@a1.mos.org.

MAY 2

Astronomy Day

▶ Farmingdale Public Library, Merrits Road, Farmingdale Long Island, New York; night observing at Robert Moses State Park at 7 p.m. Sponsored by the Amateur Observers' Society of New York. Contact Susan Rose, (516) 489-2970; website, http://members.aol.com/rjbenjamin/aos.html.

Tom Polakis

See the latest innovations in viewing equipment at the Riverside Telescope Makers Conference.

MAY 3

Northeast Astronomy Forum and Telescope Show

▶ Holiday Inn Conference Center, Suffern, New York. Sponsored by the Rockland Astronomy Club. 9 a.m. to 6 p.m. Speakers include Fred Espenak, Terence Dickinson, Dave Eicher, Roger Sinnott, Karl Hrico, and Phil Harrington. Contact Don Urban, 73 Haring Street, Closter, NJ 07624; (201) 768-6575; e-mail, DonaldUrban@Juno.com.

MAY 16–17

International Dark-Sky Association Annual Meeting

▶ Park Tucson Hotel Theater, Tucson, Arizona. Contact IDA, 3545 N. Stewart Ave., Tucson, AZ 85716; (520) 293-3198; fax, (520) 293-3192; e-mail, SaveOurSky@aol.com.

MAY 20–22

International Amateur-Professional Photoelectric Photometry (IAPPP) Meeting and Call for Papers

▶ Mile High Lake Arrowhead Resort, Lake Arrowhead, California. Contact Lee Snyder, MacLean Observatory, P.O. Box 3964, Incline Village, NV 89450; (702) 831-1931; fax, (702) 831-5535; e-mail, snyder@rigel.physics.unr.edu.

MAY 21–25

International Space Development Conference (ISDC)

▶ Hyatt Regency Milwaukee, 333 West Kilbourn Avenue, Milwaukee, Wisconsin. Sponsored by the National Space Society. For registration information contact Charlotte Nelson, (414) 466-2081; for all other matters, Peter Kokh, (414) 342-0705; website, http://www.nss.org/isdc.

MAY 22–24

Huron Valley Astronomers Special Star Party

▶ Hwy. 269, south of Bellevue, Ohio. Sponsored by TECH2000. For registration contact TECH2000, 3349 SR 99 South Monroeville, OH 44847; (419) 465-2997; e-mail, tddi@accnorwalk.com; website, www.accnorwalk.com/~tddi/tech2000/.

MAY 22–25

Riverside Telescope Makers Conference

▶ Camp Oakes in the San Bernardino Mountains, near Big Bear, California. Contact RTMC c/o Fox & Stephens, CPAs, 9045 Haven Avenue, Suite 109, Rancho Cucamonga, CA 91730; (909) 948-2205; e-mail, robert_stephens@

eee.org; website, http://home.sprynet.com./sprynet/hrmeyer/rtmchome.htm.

MAY 23

Hurricane Ridge Star Party

▶ Olympic National Park, Port Angeles, Washington. Contact John Gallagher at (360) 452-0260; fax, (360) 452-0256; e-mail, jgalla@orca.esd114.wednet.edu.

MAY 29–31

Southern Star Astronomical Convention and Star Party

▶ Wildacres Retreat, near Little Switzerland, North Carolina. Sponsored by the Charlotte Amateur Astronomers Club. Contact Gayle Riggsbee, (704) 846-3136; e-mail, geomar@trellis.net.

RESOURCES

When Galaxies Were Young (page 44)

Next Generation Space Telescope: Visiting a Time When Galaxies Were Young, (Association of Universities for Research in Astronomy, Washington, 1997). A booklet detailing the various designs and plans for the Next Generation Space Telescope.

Cosmic Jekyll and Hyde (page 50)

The New Astronomy, second edition, by Nigel Henbest and Michael Marten, (Cambridge University Press, 1996). A comprehensive guide to the electromagnetic spectrum, chapter 9 discusses ultraviolet astronomy.

The following websites contain beautiful images taken by the Ultraviolet Imaging Telescope: http://fondue.gsfc.nasa.gov/UIT/Astro1/Astro1_pictures.html and http://fondue.gsfc.nasa.gov/UIT/Astro2/Astro2_pictures.html.

Crack in the Clockwork (page 54)

Newton's Clock: Chaos in the Solar System, by Ivars Peterson, (W. H. Freeman and Company, 1993). A definitive and accessible book about how astronomers came to understand the role of chaos in the solar system.

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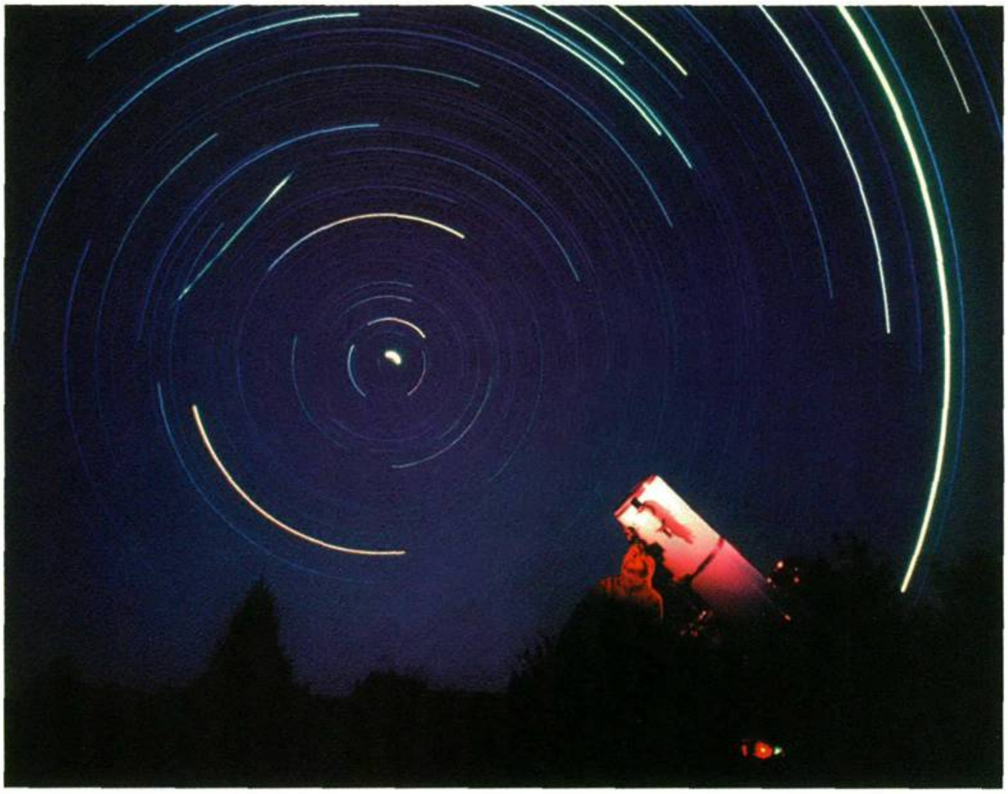
Dancing Planets, Streaming Lights

A three-planet alignment competes with the majesty of the Northern Lights

▶ It was a starry summer night and unusually clear and dry for the Midwest. A light breeze flowed over the hills and fields, shooing away the mosquitoes and providing for a perfect night of stargazing. A planetary alignment and great weather conspired to coax this raw astronomy recruit away from the city, armed with a bargain 4-inch reflector and even cheaper binoculars — though, in fact, I didn't need either one to spot the evening's extraordinary cosmic events.

Bright Venus, angry Mars, and proud Jupiter formed a small triumvirate against the black sky. The formation was so tight that, with my arm extended above my head, I could obscure the entire triangle with nothing more than the tip of my thumb.

By 10:30 p.m. the reflector was set up. Everyone was

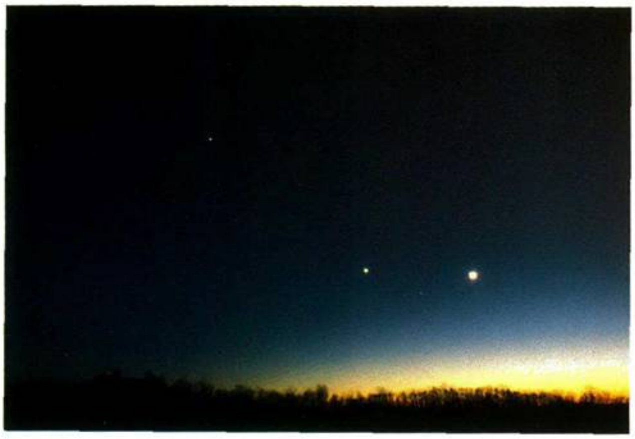


A Meteor Shoots Through Star Trails

JERRY LODRIGUSS

JOHN MARTINEZ

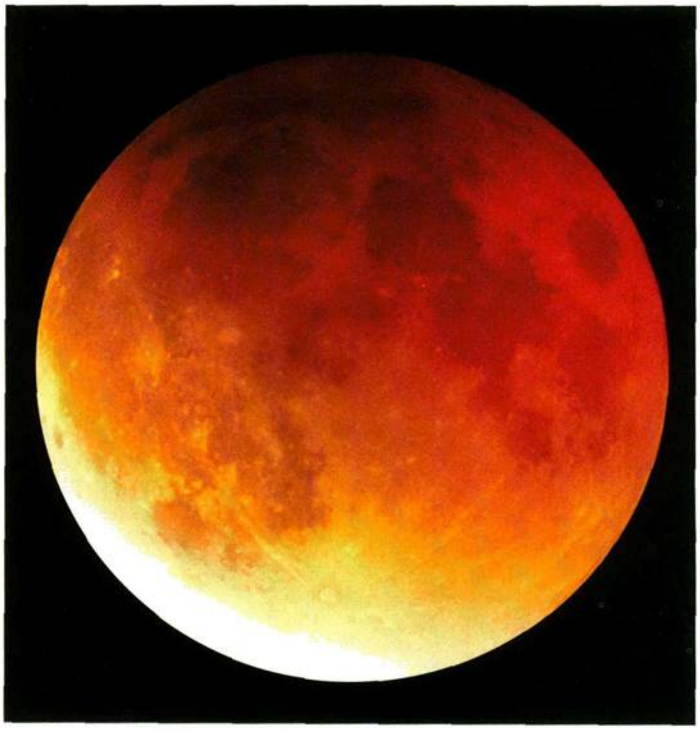
(18mm lens at f/3.5,unhypered Kodachrome 64 film, 5.5-hour exposure taken December 1998)



Jupiter, Venus, Mars, and Moon

JEAN-PAUL D. LANDRY

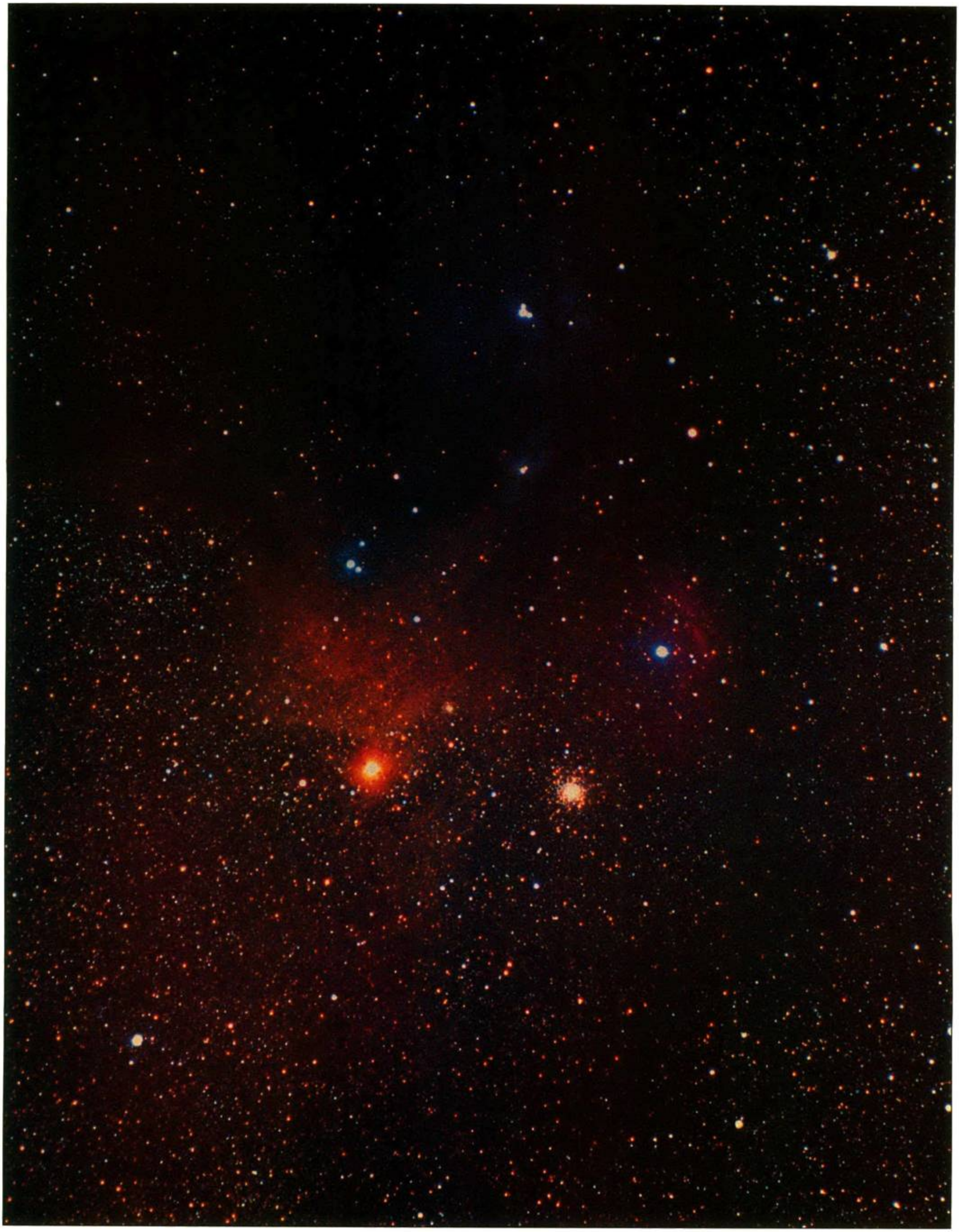
(28mm lens at f/2.8, Provia 1600 film at 800 ISO, 20-second exposure taken December 2, 1997)



Luna Eclipsed

CHRISTIAN VILADRICH

(8-inch f/6.5 SCT, Ektacolor Gold Pro 400 film, 10-second exposure taken September 16, 1997)



Rho Ophiuchi Region

BOB AND JANICE FERA

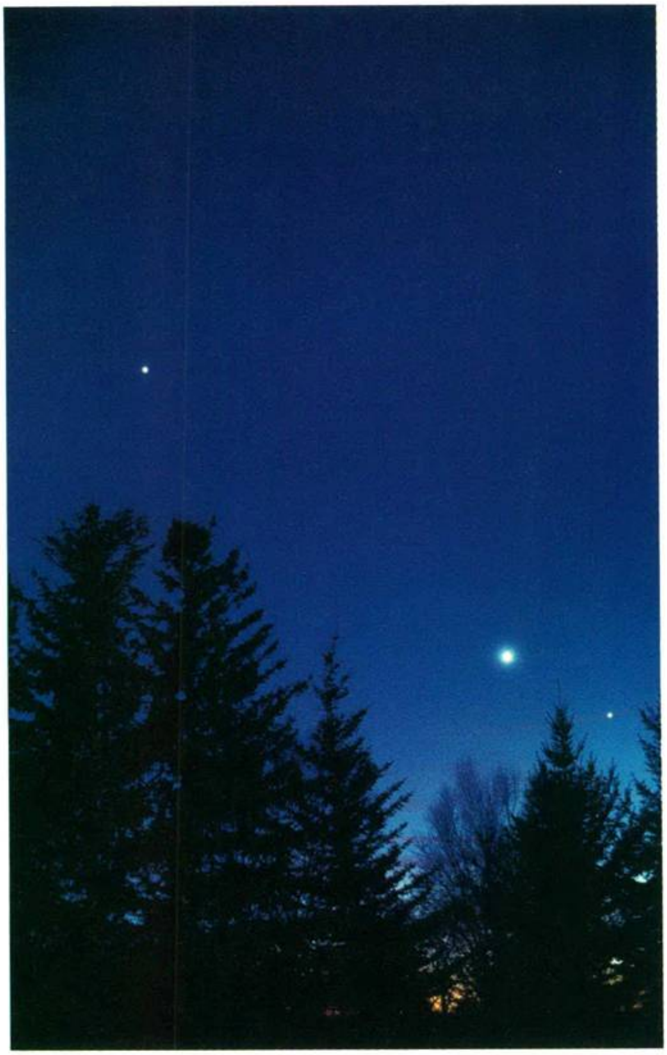
(200mm lens at f/4, hypered Kodak PPF 400 film, composite of two 20-minute exposures) so focused on the tangle of planets that the real light show was launched from the north without our knowledge. When we finally turned to Aurora Borealis, the Northern Lights, it was dream-like: Glowing piers reached into the sky until they produced a crescendo of light, forming what appeared as a surrealistic cathedral wall of buttresses, arches, and columns. I'd never seen the Northern Lights so far south — at the 40th parallel. All eyes turned north as now, from east to west, the inky darkness lifted from the night. The planets were just a sideshow to this streaming light flowing up from Earth.

We focused all attention on the aurora for some time, until a glance back to the host planets in the west demanded that we take a second long look at a phenomenon that had gone undetected while we were diverted by the lights in the north. A new light had come, a solar storm of some sort. It looked almost like a steady stream of light forming a rope between Earth and the three aligned planets. No one among us had ever seen such a sight: true interplanetary dynamics.

Sometime after midnight the cascade created by the aurora began to dissipate. As the sky faded, quiet sadness slowly took the place of light. We savored every last moment.

Finally, in the darkness, the planets gone beyond the horizon, we packed up our optics and prepared to leave. This raw recruit went home content — a better student of the sky. ▣

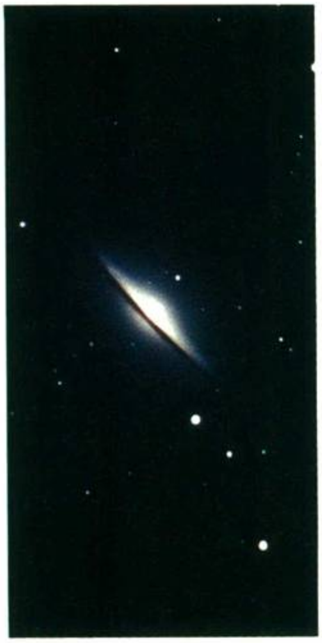
Tom Hood can sometimes be coaxed to leave the city lights of West Chicago and go observe.



Planets Get in Line: Jupiter, Venus, and Mars

RANDALL WEHLER

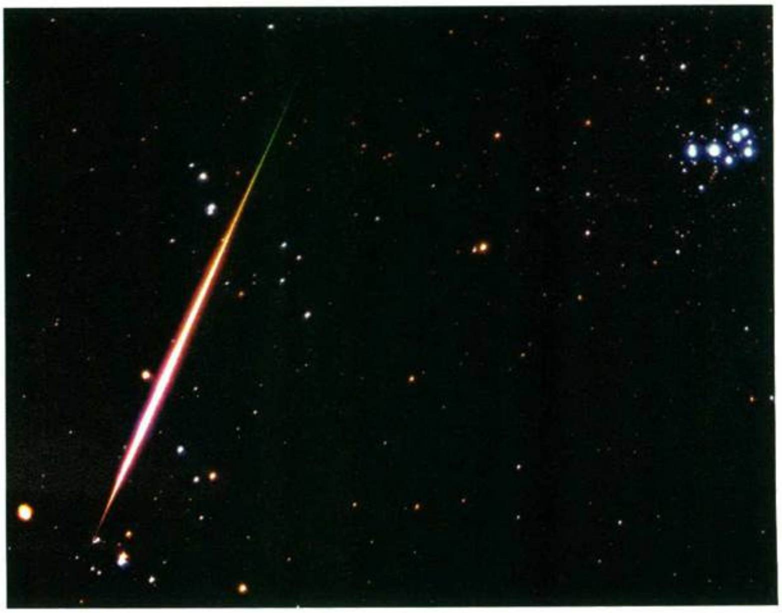
(50mm lens at f/2.8, Kodak Elite II 200 film, 2-second exposure taken December 12, 1997)



The Sombrero Galaxy (M104)

W. A. TREMBLY, JR.

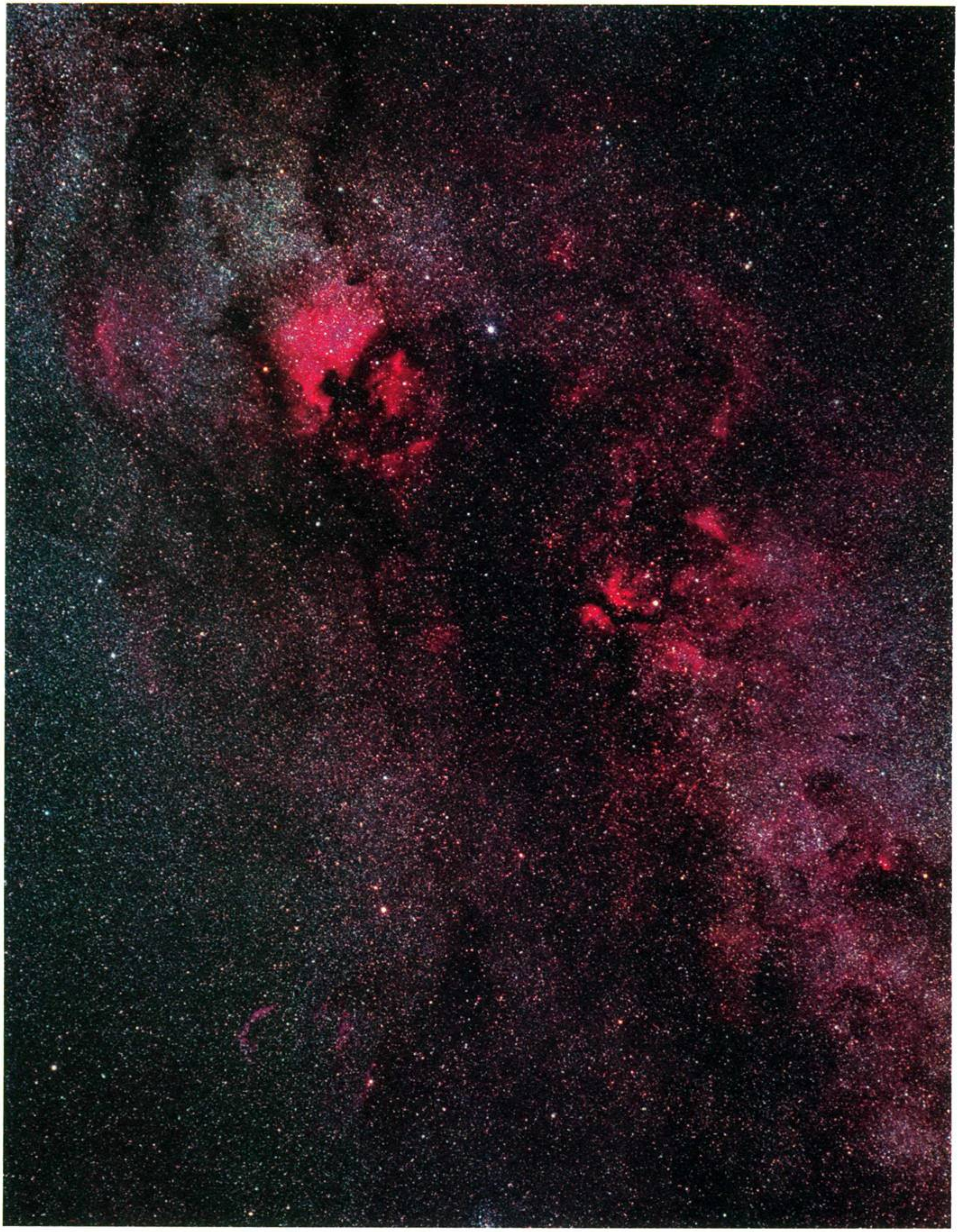
(11-inch f/10 SCT, hypered Kodak PPF 400 film, composite of two 90-minute exposures)



A Perseid Meteor Zips through Taurus

JAMES SENTER

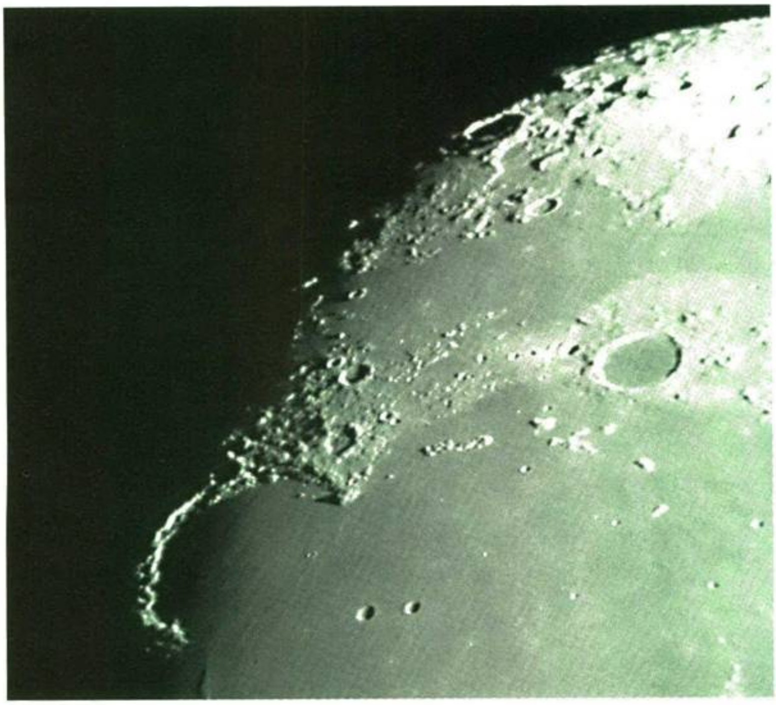
(50mm f/1.4 lens, Fuji Super G 800 film, 4-minute exposure taken August 11, 1997)



The Spine of the Milky Way in Cygnus

TONY AND DAPHNE HALLAS

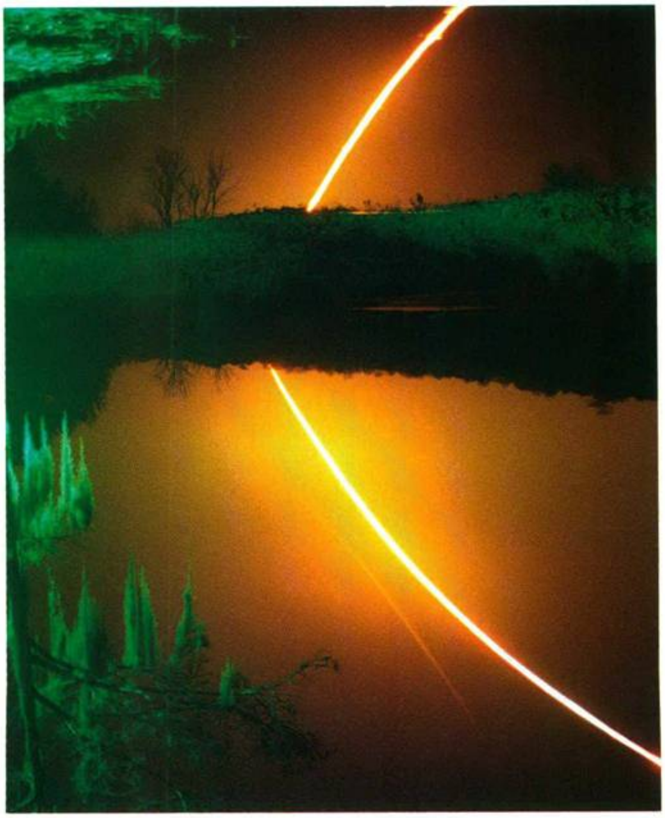
(165mm lens at f/5.6, hypered 6x7 120 PPF film, composite of two 30-minute exposures)



A Dramatic Moonscape

FABIO FALCHI

(8-inch SCT at f/65, Ektachrome 200 film, 2-second exposure taken April 26, 1988)



Space Shuttle Discovery Launches

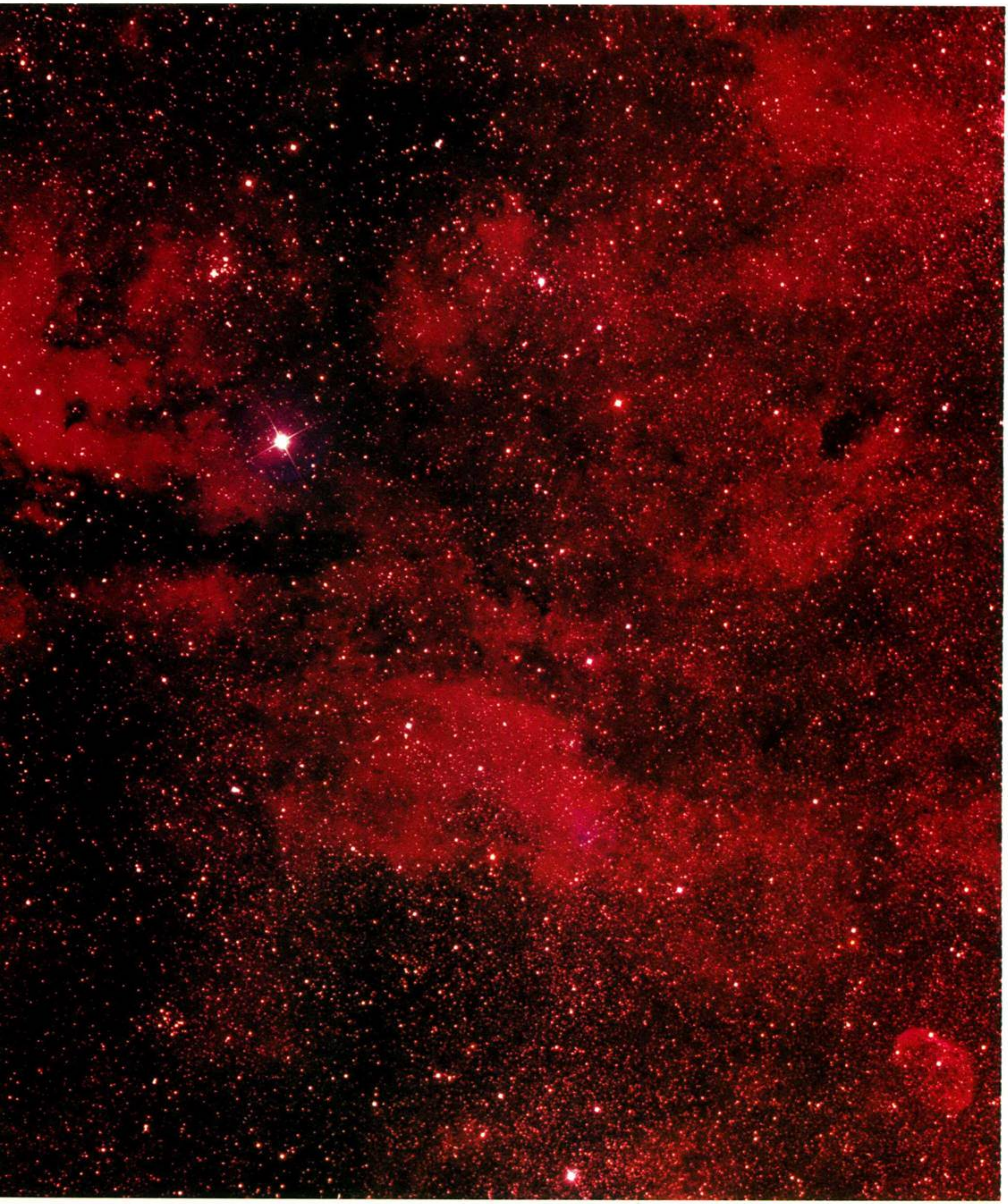
TIM DELONG

(35mm lens at f/8, Kodak Gold 100 film, 90-second exposure taken February 3, 1995)

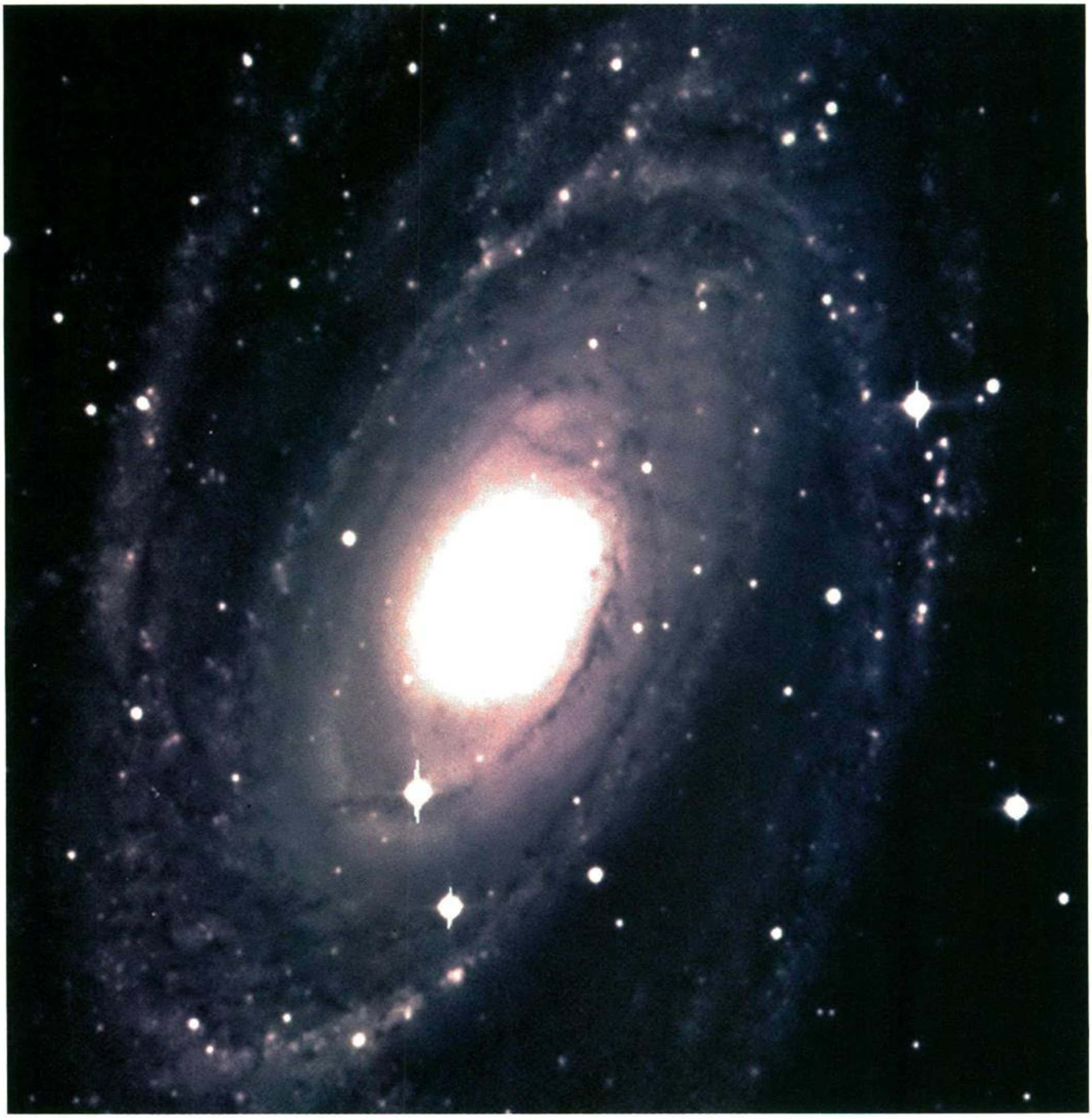
Gamma Cygni

JASON WARE

(12-inch f/2.2 Schmidt camera, Fuji HG 400 film, composite of two 7-minute exposures)



This month's best astrophoto



M81 in Ursa Major

TIM PUCKETT

(24-inch f/5 Ritchey-Chretien scope, Apogee AP7 CCD camera, composite of 10-minute red, green, and blue exposures)

One of the brightest spiral galaxies, M81 is a member of the Ursa Major group of galaxies, which lies about 10 million light-years away. In photographs, M81 is often seen paired with its companion galaxy M82. It offers splendid spiral arms to viewers with large or small telescopes.

To see our on-line photo of the week, visit our website at http://www.astronomy.com.

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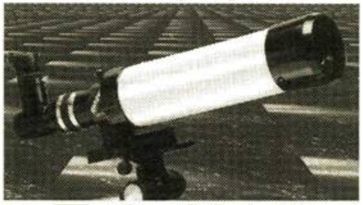

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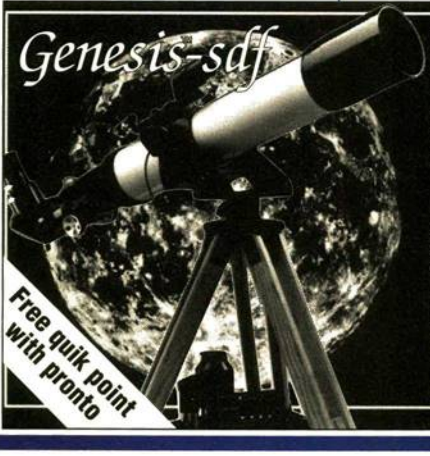

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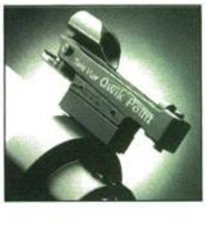

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Photo of Horsehead Nebula taken with Pronto by Ralph Sieger

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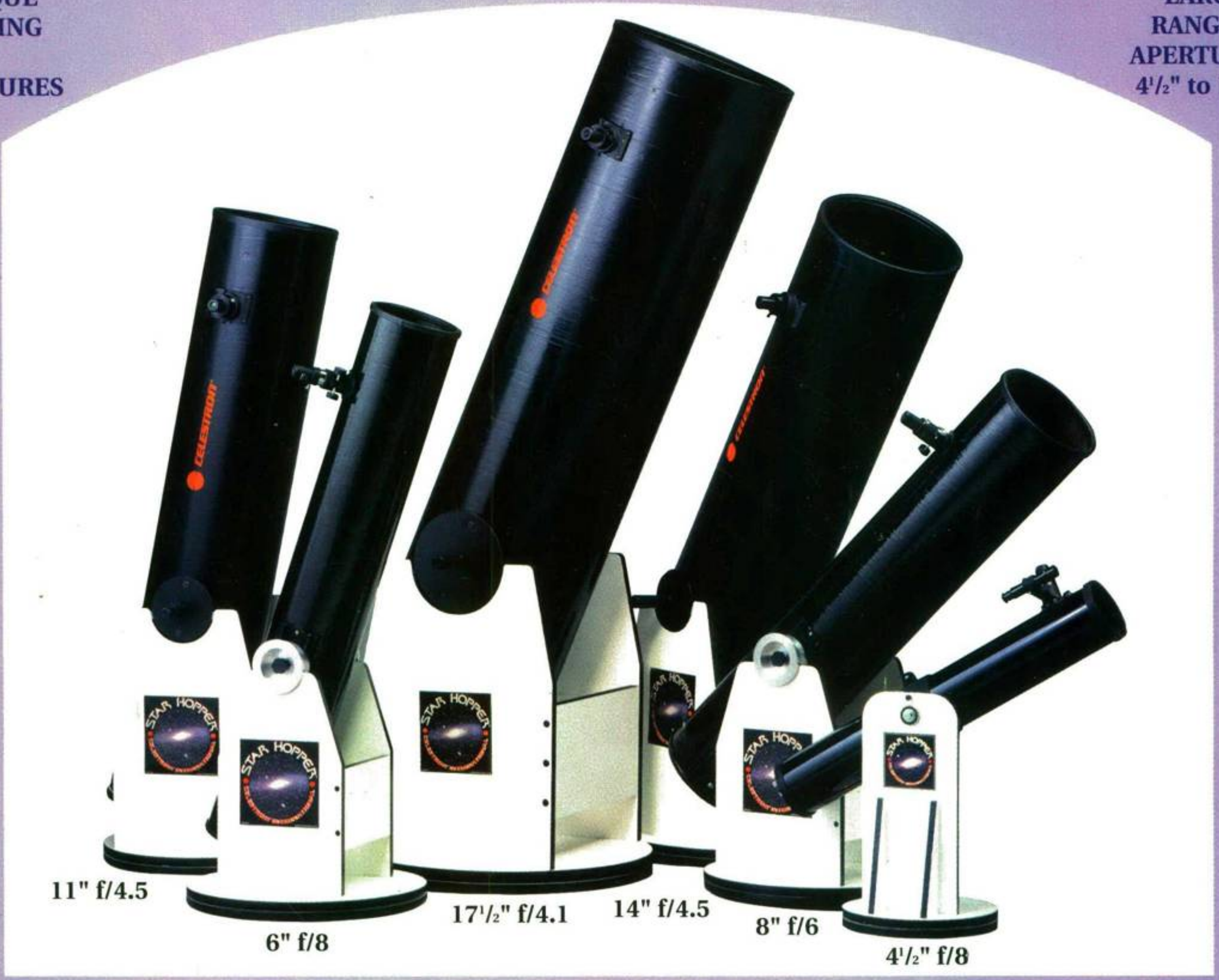

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✓ Includes a 10mm SMA Wide Angle Eyepiece – 1¼" Moon Filter – 1¼", 6x30 Finderscope with bracket, LED Flashlight, Celestron Deluxe Sky Maps.

PACKAGE C

✓ Includes a 7.5mm Multi-Coated Plössl Eyepiece – 1¼", 17mm Multi-Coated Plössl Eyepiece – 1¼", 9x50 Finderscope with bracket, Night Vision Dual LED Flashlight, CD-Rom "The Sky for Celestron"

CELESTRON® *For more detailed information on these telescopes, contact a Celestron dealer or Celestron. Visit our Web site at http://www.celestron.com*

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